The American Journal of Surgery

EDITED BY THURSTON SCOTT WELTON, M.D.

TRAUMATIC SURGERY

Papers Read at the June 1947
Meeting of The American Association
for the Surgery of Trauma

FIFTY-SIXTH YEAR OF CONTINUOUS PUBLICATION

November 1947

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serosa-to-serosa or end-to-end

Fibrin deposited at red arrows (↓) makes anastomosis gas and water tight

mucosa pouting through

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NUMBER FIVE (CONTINUED)

Fascia

end-to-end or overlapped

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Fascia above and below sutured

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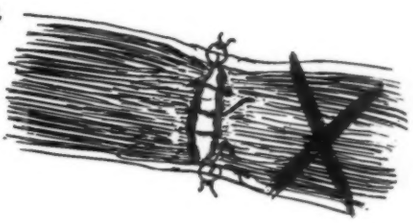

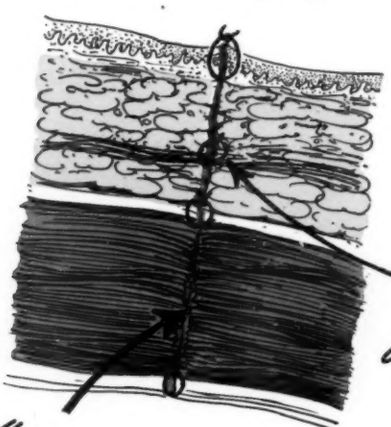

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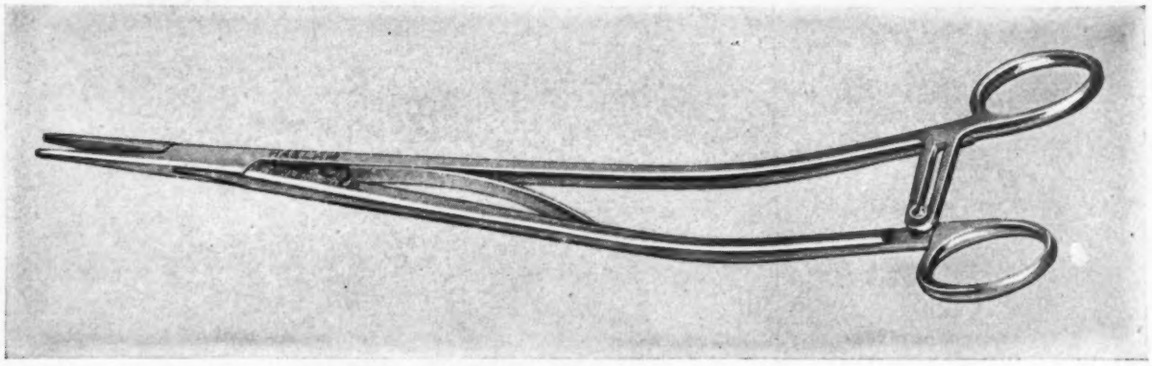

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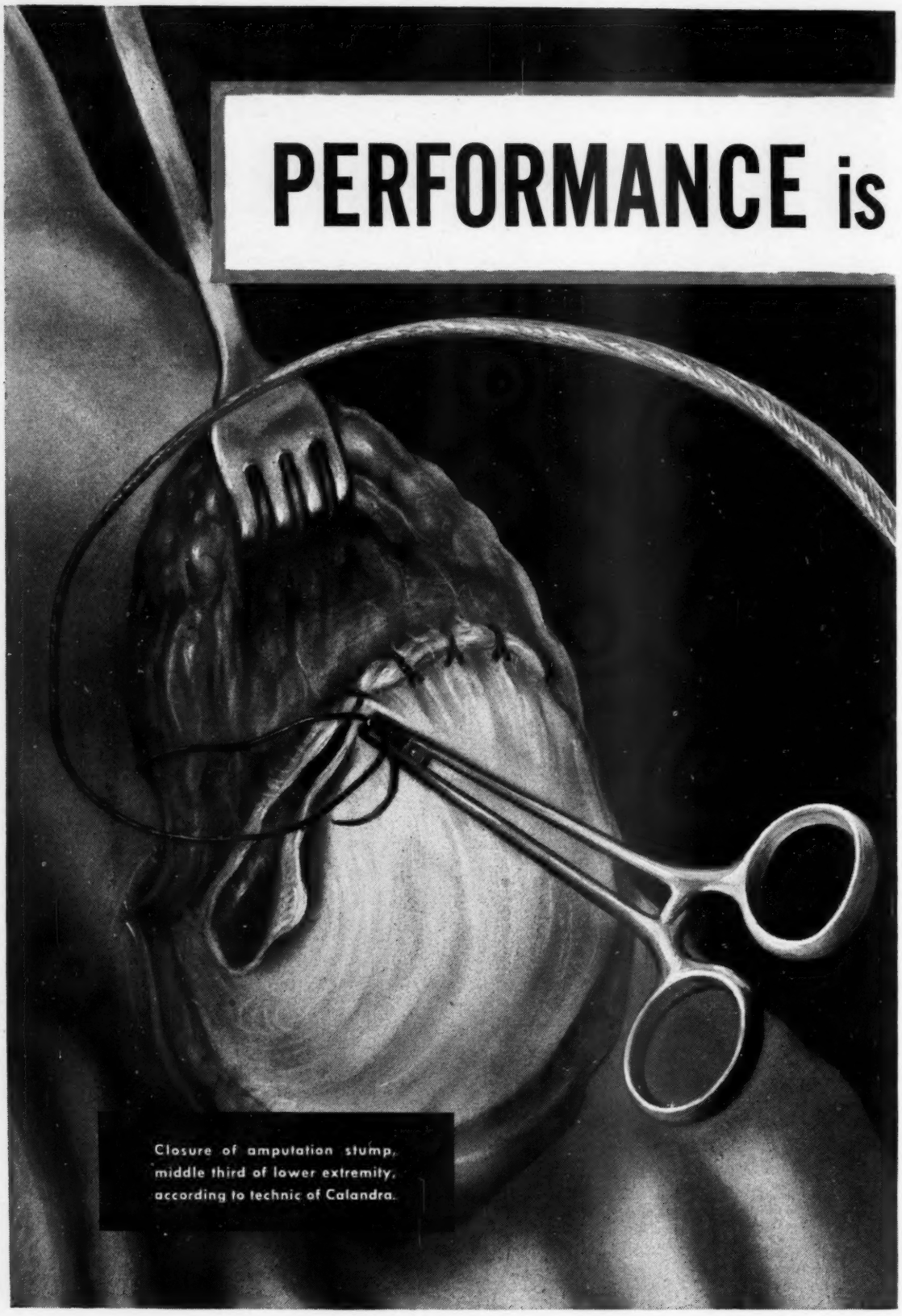
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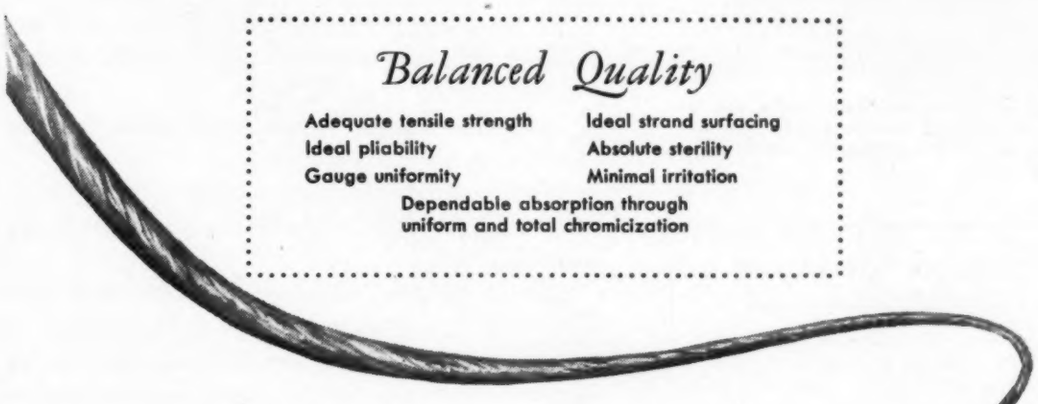

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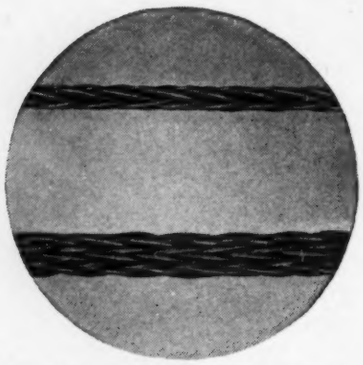

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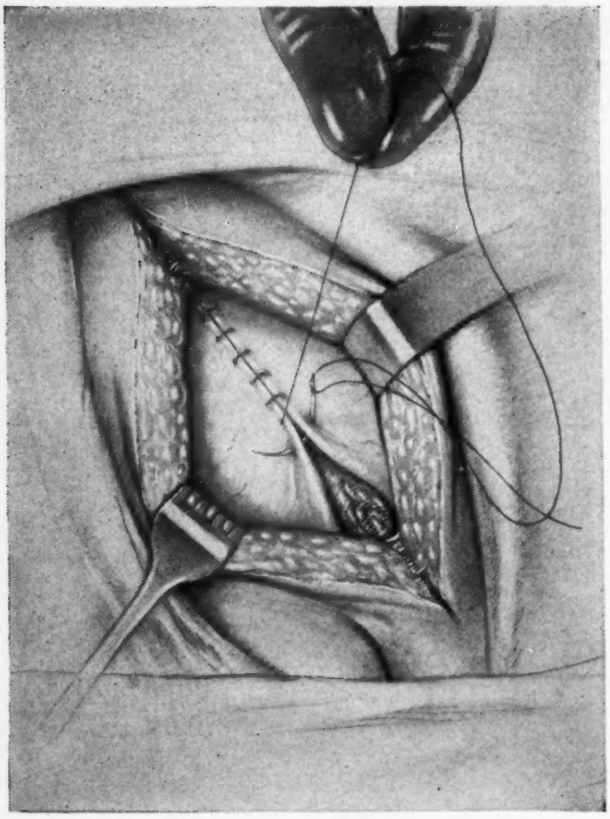

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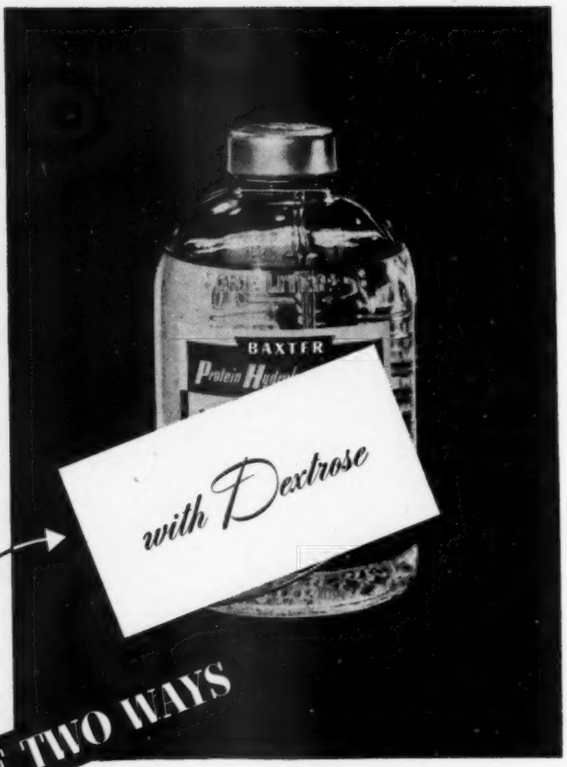

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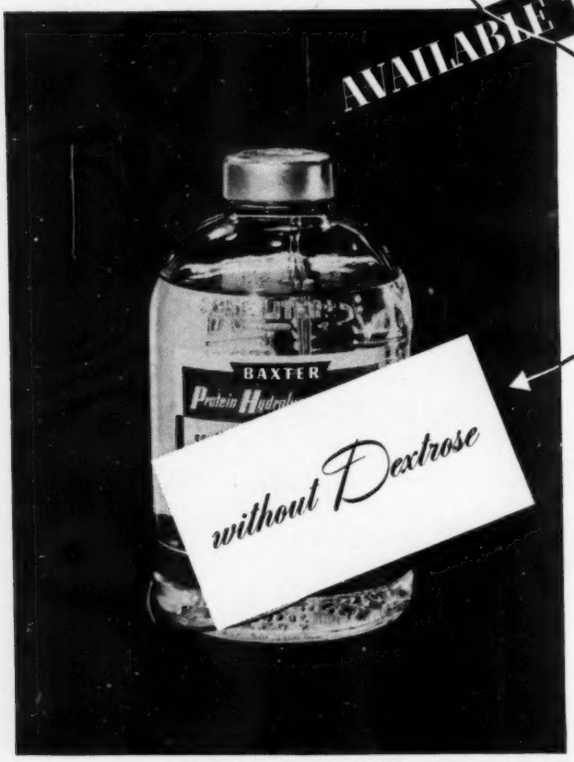

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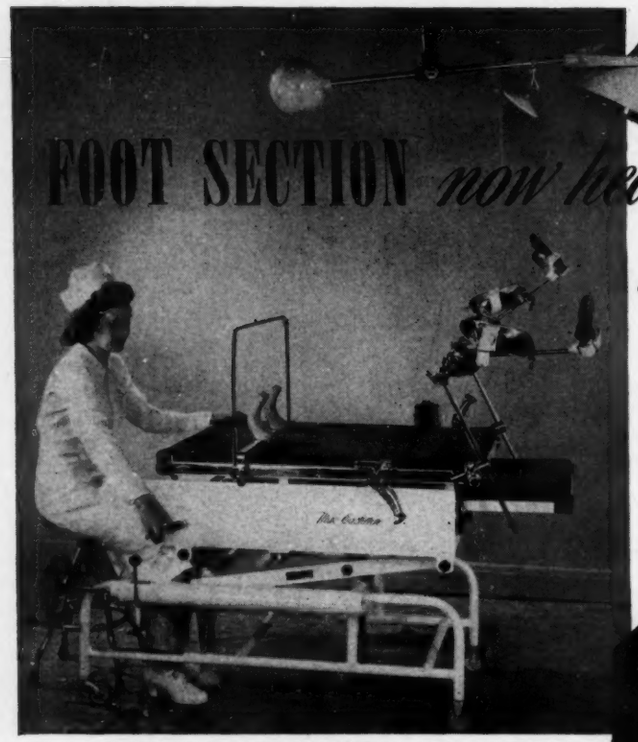

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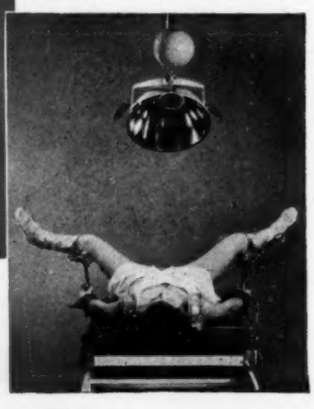

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references: *VITALLIUM SKULL PLATES, Geib, F. W. Jour. Amer. Med. Assn. 117-1, July 5, 1941.

*REPAIR OF DEFECTS IN SKULL BY READY MADE VITALLIUM PLATES, Beck C. S. Jour. Amer. Med. Assn. 118-10 Mar. 7, 1942.

*REPAIR OF CRANIAL DEFECT BY INSERTION OF A VITALLIUM PLATE, Parsons, W. H. South. Surgeon XI-12, Dec. 1942.

*Reprints available on request.

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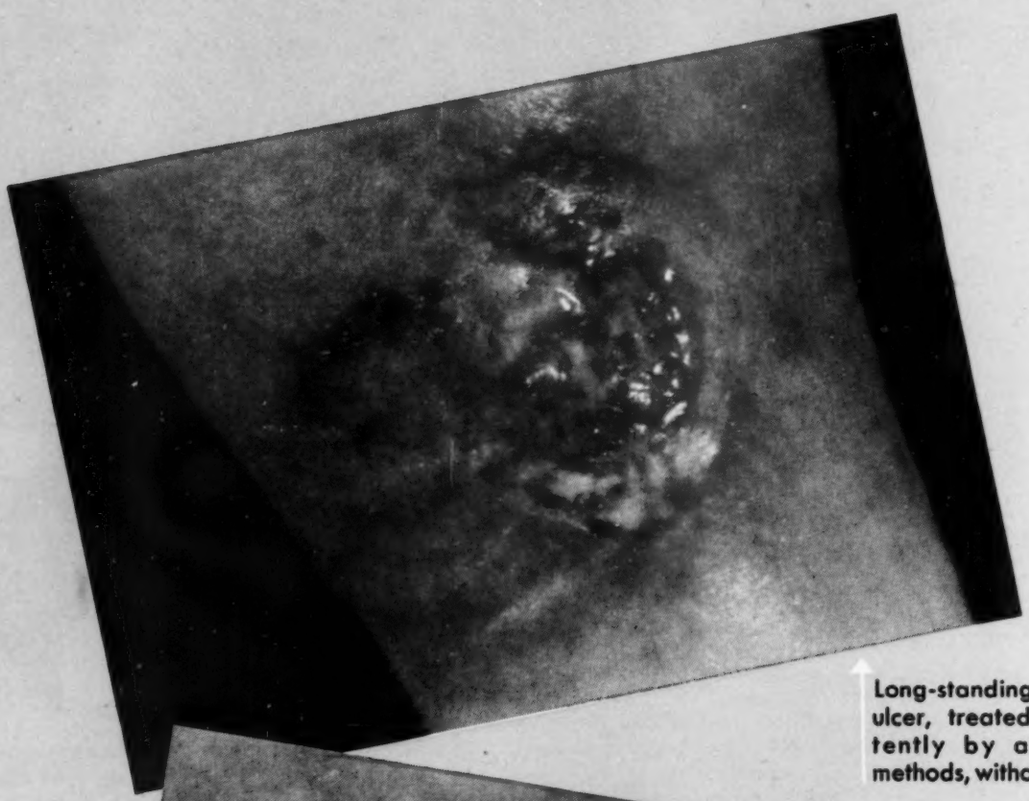

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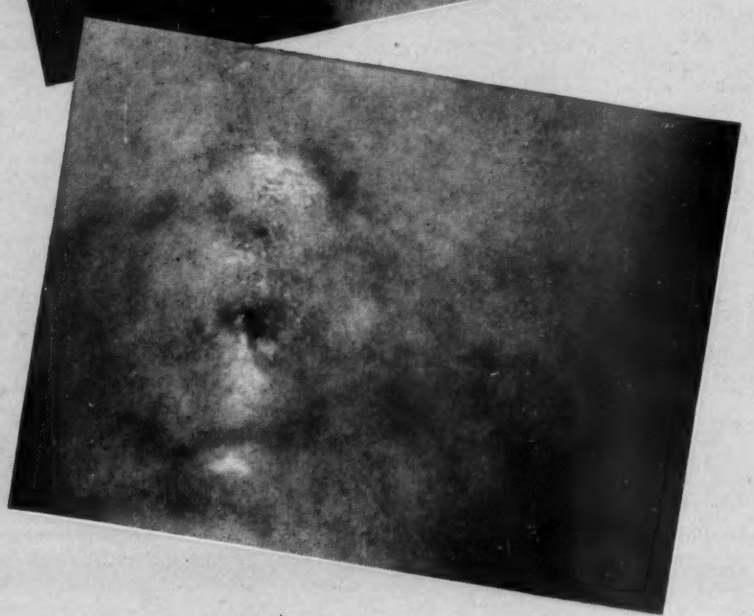

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1. Hardin, P. C.: So. Surg. *10*:301 (May) 1941.
2. Brougher, J. C.: West. J. Surg., Obst. and Gyn. *52*:520, 1944.

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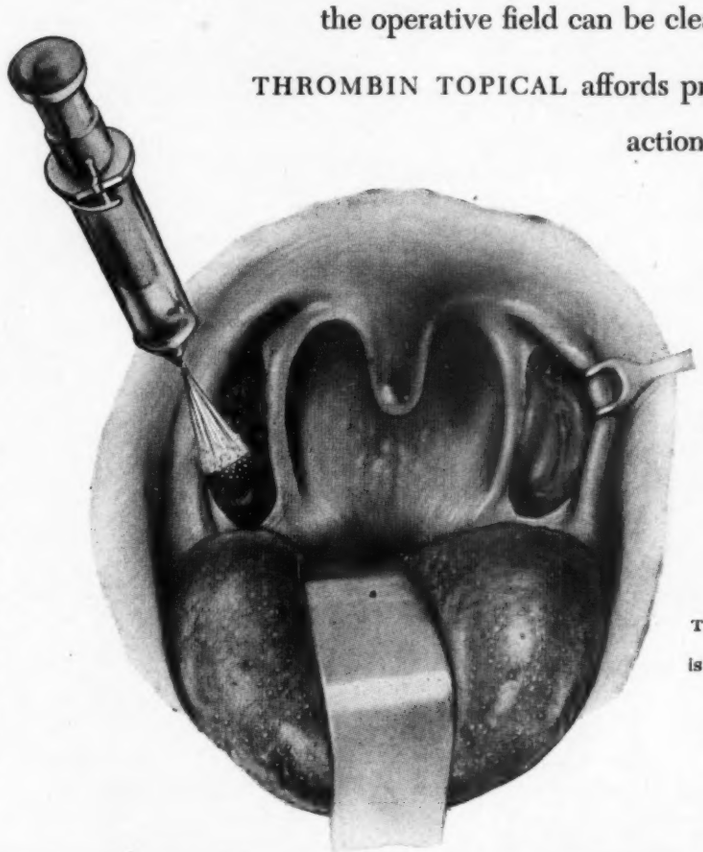

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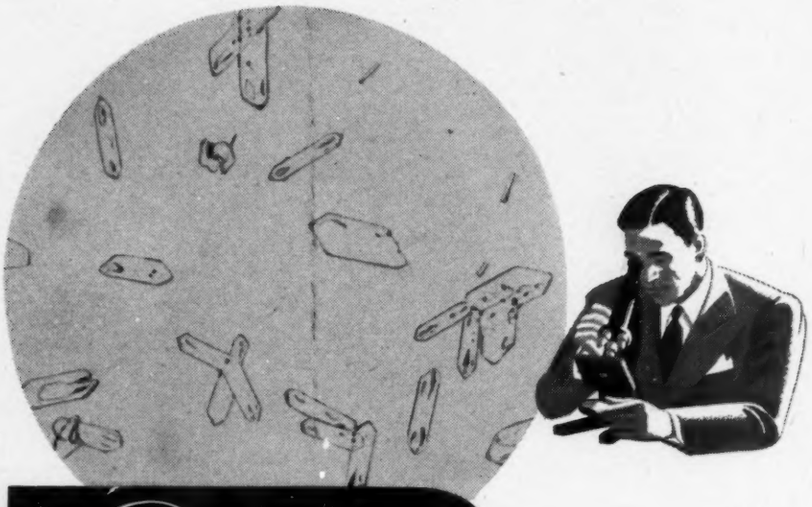

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*Lehr, D.: Proc.Soc.Exper.Biol.& Med. *58*:11 (Jan.) 1945

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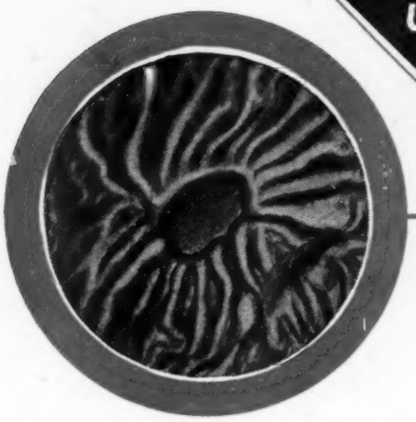

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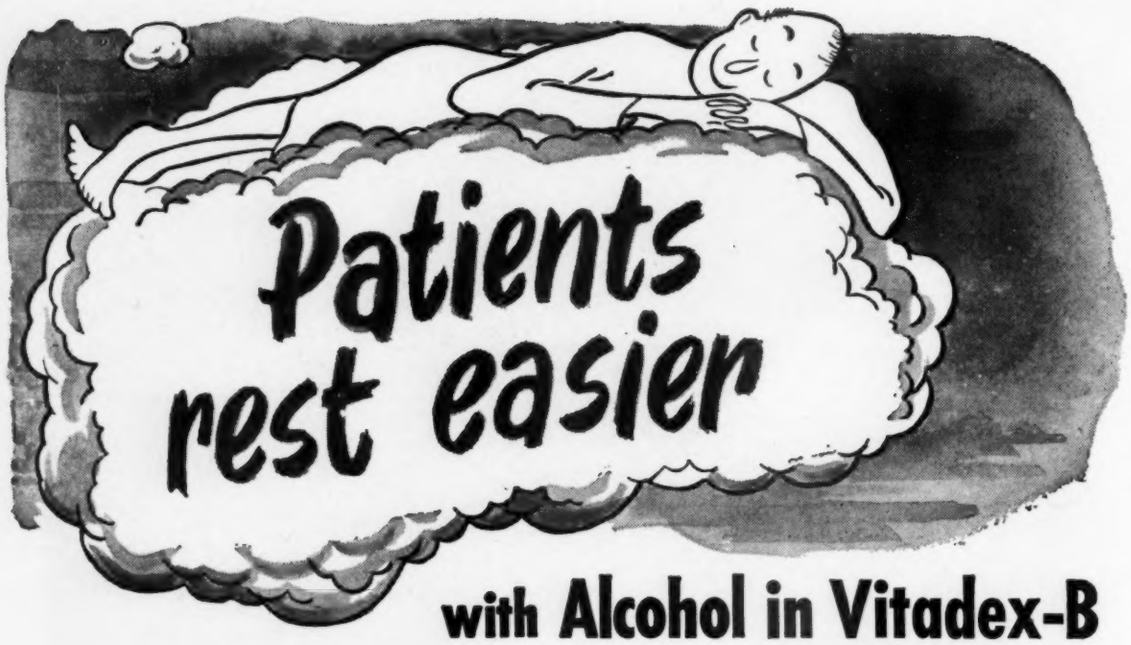

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*Behan, R. J., *Am. Jour. Surg.*, *89:227-229, Aug., 1945*
Moore, D.C. and Karp, M., Surg. Gyn. Obst., 80:523-525, May, 1945
Craddock, F H., Jr., Craddock, F. H., Sr., Mr. of Med. Assoc. of Alabama, Nov., 1942

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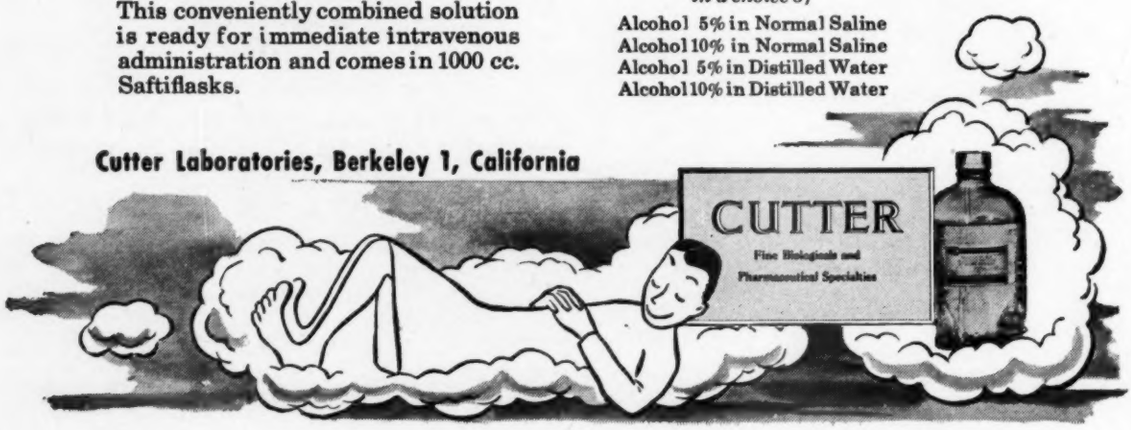

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*Flippin, H. F. and Reinhold, J. G.: Ann. Int. Med., 25:433 (Sept.) 1946.

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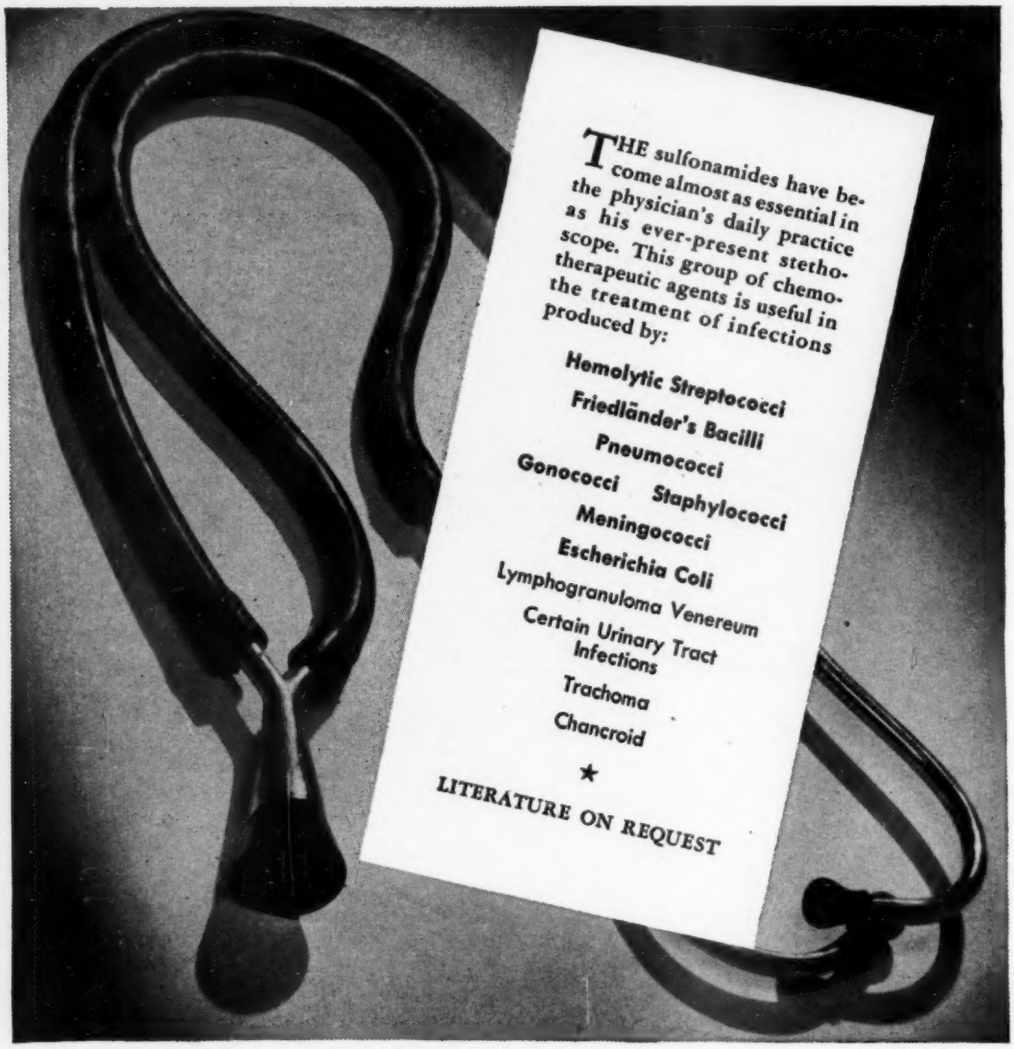

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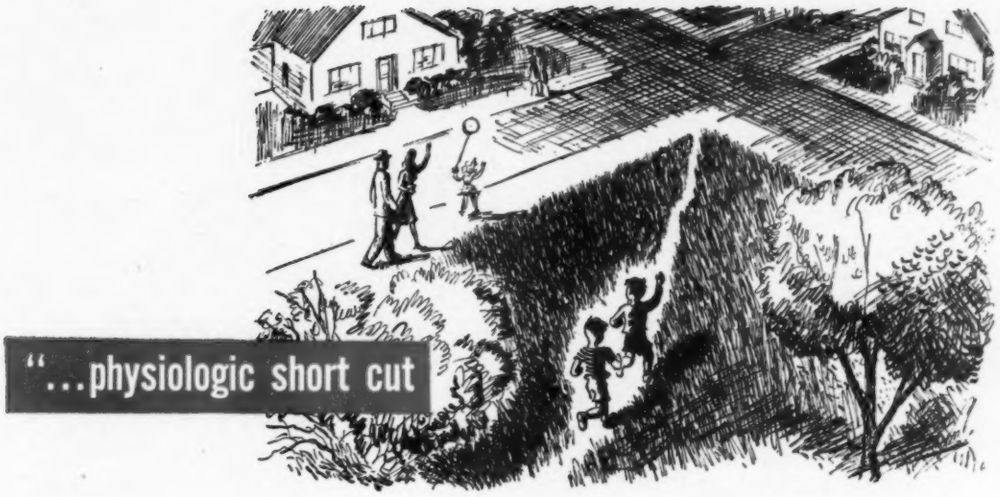

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1. Editorial: J. A. M. A. 121:346, 1943
2. Nadal, J. W.: Northwest Med. 46:444, 1947
3. Sprinz, H.: M. Clin. North America 30: 363, 1946
4. Brunschwig, A., Clark, D. E., and Corbin, N.: Mil. Surgeon 92:413, 1943

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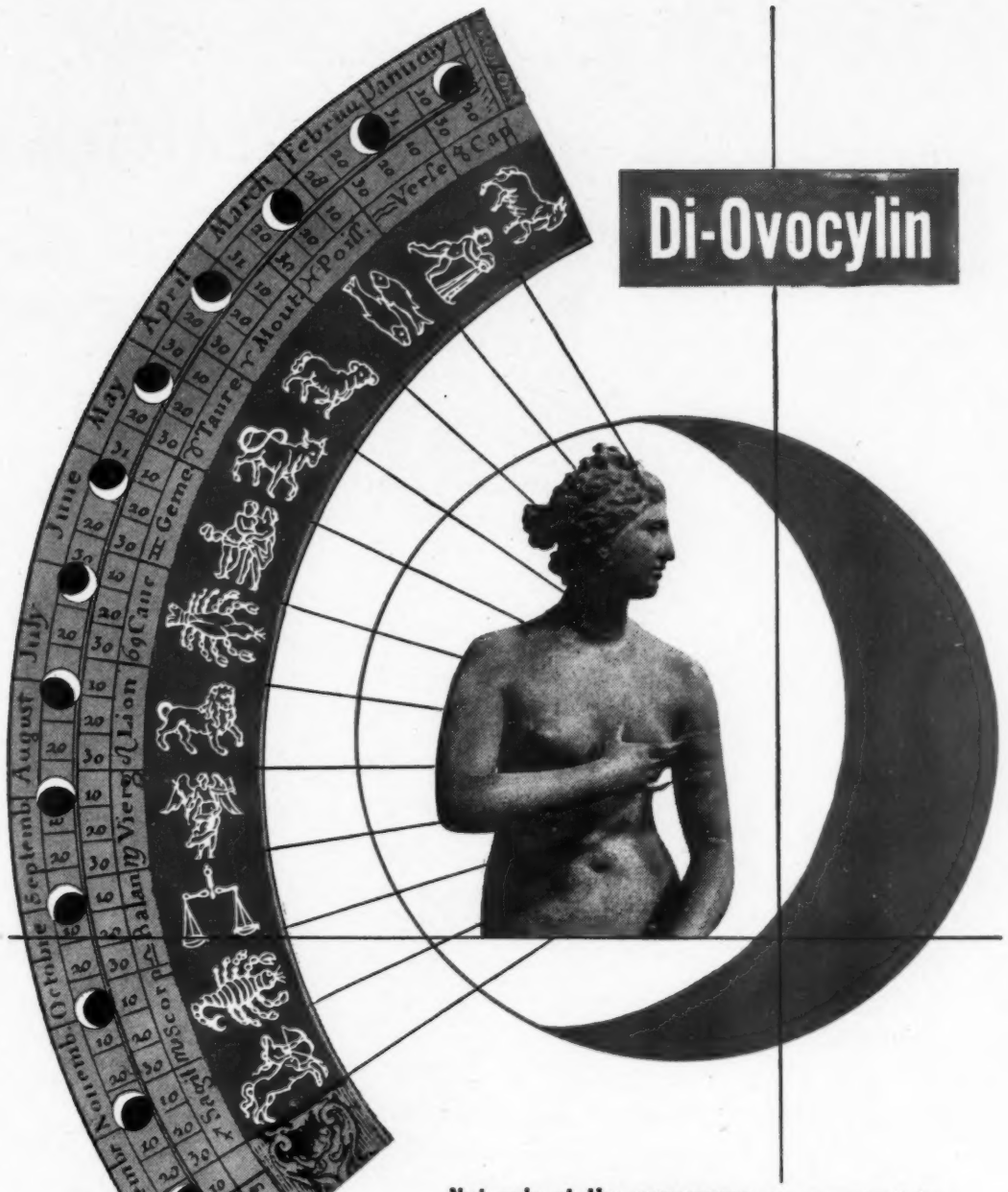

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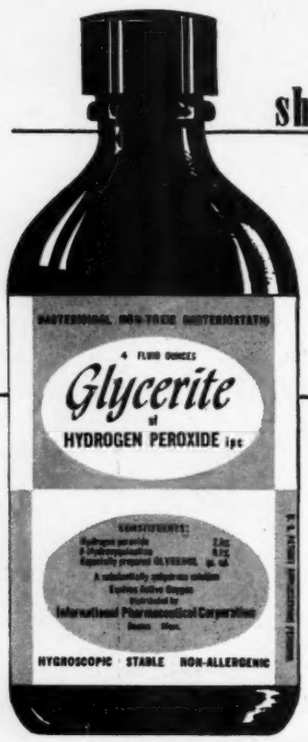

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Bibliography: *New Eng. J. Med. 234:468, 1946. J. Invest. Derm. 8:11, 1947. Science 105:312, 1947. Am. J. Surgery 74:428, 1947*

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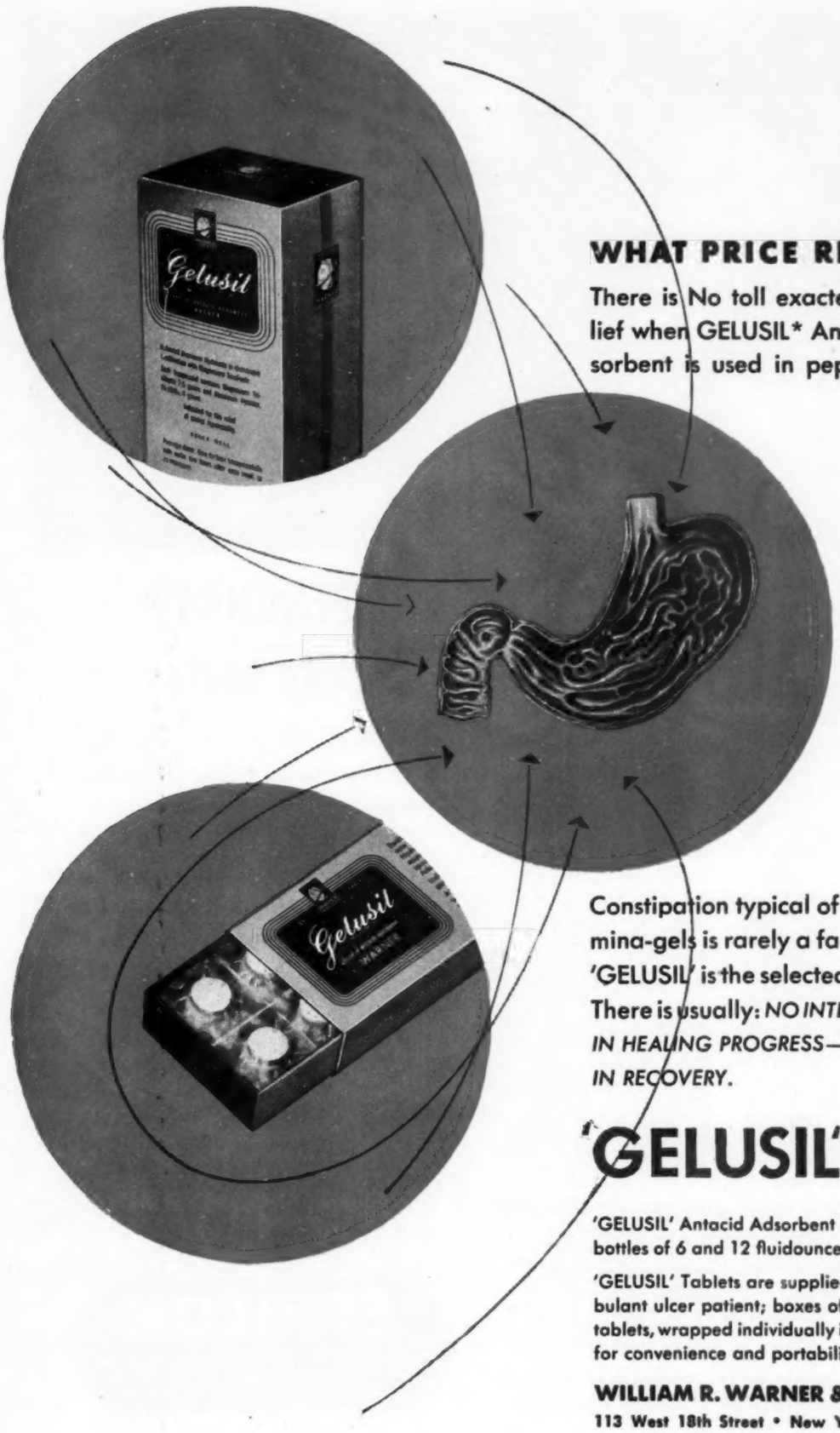

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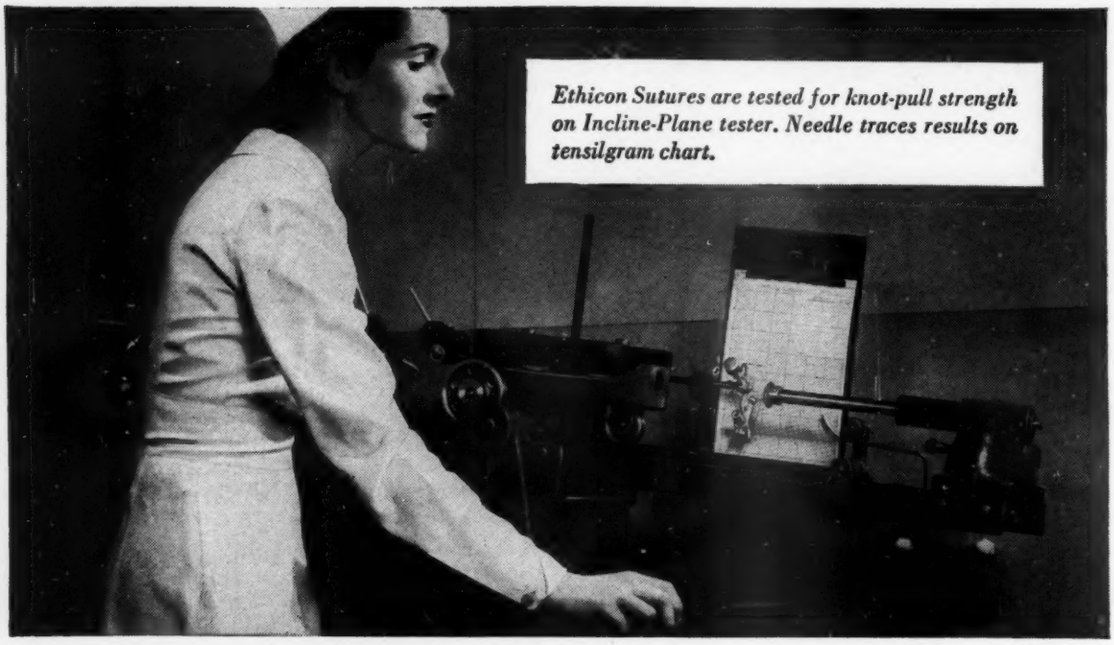

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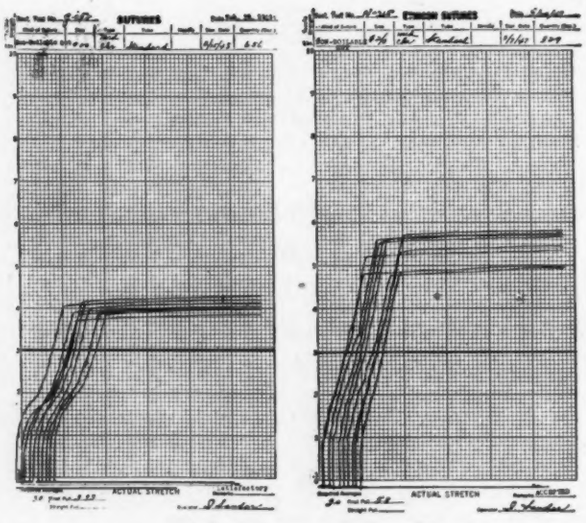

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VOL. LXXIV NOVEMBER 1947 NUMBER FIVE

Editorial

PRESIDENTIAL ADDRESS

RALPH G. CAROTHERS, M.D.

Cincinnati, Ohio

SOME years ago when I helped write the constitution of this Association I did not realize that someday I would be elected president and have to make a presidential address. Had I been able to see that far into the future I still do not believe I would have realized how difficult such a project could become. However, I will do the best I can for I believe that no matter how arduous a task, it is a small price to pay for the honor of having been elected your president.

Years have passed now since this Association was organized and this is only our seventh session; had it not been for the war it would have been our ninth. And we really had one other, namely, the organization meeting in San Francisco in 1938. Therefore, this should have been our tenth meeting. As a result of the passage of time some familiar faces have disappeared and many new ones have come in. I shall try to address most of my remarks to these new members so they may, in a way, catch up with the aims and traditions of this Association and know something about the origin.

It was a very cold rainy day in December, 1937, when a small group of us sat together at luncheon at the meeting of the Western Surgical Association in Indianapolis. Among those who are present were: Drs. Edgar L. Gilcreest, Eslie Asbury, William Cubbins, Arthur Metz and I. There may have been some others but I do not remember now who they were, nor do I remember just how the subject of trauma came up. However, it was evident that we who were sitting together were very much interested in that subject and were not getting too great a kick out of some of the other papers which were being read at the meeting we were then attending. The net result of the matter was that suggestions were made for the formation of an association such as we have today. As a matter of fact, we talked about it so much that we decided to hold another meeting the following week in Birmingham, Alabama, where the Southern Surgical Association was convening. At that meeting several more were added to our little gang, as it were, and we talked loud and long of the possibilities of forming the association. The net result was that a temporary committee was organized of which Dr. Gilcreest was made chairman and I the secretary.

Others on that committee were: Dr. William L. Estes, Jr., of Bethlehem, Pennsylvania; Dr. Charles C. Green of Houston, Texas; Dr. R. Arnold Griswold and Dr. Frank P. Stricker of Louisville, Kentucky; Dr. Kellogg Speed, Dr. Albert H. Montgomery and Dr. Arthur R. Metz of Chicago; Dr. Ross A. Woolsey of St. Louis and Dr. George W. Swift of Seattle.

This was followed as months went on by many trips on my part and also on the part of

Dr. Gilcreest to various parts of the country to interview and discuss the matter with many men. In addition to this a great many letters were written. As a result of these many interviews, many of which were held all the way from New York to Los Angeles and up into Canada, a good list of men who might be interested in such an association was developed.

A letter was drafted after consultation with various members of the committee, the letter was signed by Dr. Gilcreest and sent out to the men who were on our list. These men were invited to meet in San Francisco on June 14, 1938, which was Tuesday of the week of the meeting of the American Medical Association.

A goodly number appeared at that meeting and the association was formally organized and set into motion. Dr. Kellogg Speed was made the first president, Dr. Edgar L. Gilcreest the president-elect, Dr. Frazer B. Gurd, vice president, Dr. Arthur R. Metz, treasurer, and Dr. R. Arnold Griswold, historian, and I secretary. The council which was also elected at the same time consisted of: Drs. Casper R. Hegner, Charles C. Green, Hubley Owens, Gordon M. Morrison and Grover C. Penberthy.

Now it may be interesting to the younger members here today to know why we were motivated to form such an organization. The reason was a simple one. We were interested in the surgery of trauma and most other surgeons were not. All of us were members of one or more of the older, well organized, surgical organizations and we had attended meetings regularly and enjoyed them very much. But we heard very little on the subject of trauma. In fact, this has been true for sometime.

Some years ago trauma played a large part in the work of the surgeons of any one large city hospital. In fact, there was in those days, just surgery, general surgery it was called, and it included practically everything in the entire field. There are men living today who have done operations from the eye to the toes. Sir Berkley Moynihan treated fractures, or at least his house surgeon did; Hugh Owen Thomas wrote on peritonitis and there was the Lane plate and the Lane kink. The scope of surgery had not been developed to the extent that it is today, and trauma occupied a very large part of what there was. However, at about the turn of the century before automobiles had become common and before the machine age of today, specialism began to appear in surgery. This was brought about partly by the improvement in anesthesia, operating technic and the development of new instruments. The result was that more and more surgeons became interested in elective surgery and more and more operations within the cavities of the body were performed. These operations were more exciting; they paid better; they could be done at a more convenient time. There was more drama in this newer surgery. After all, cutting off a man's leg was not much different from cutting off a horse's tail, but to go into the abdominal cavity and remove some part of the stomach and put it all back together—well that was as thrilling as a Blalock operation is now. The development of the specialities and the multiplication of instruments became so great that after a while it seemed impossible or at least improbable that anyone would master the technic of more than one or two specialities.

Now the development of the surgical specialities was, in many respects, a good thing. The field was broadened to a tremendous degree. New surgical approaches to many old diseases which had proved incurable in the past were developed. A great deal of good came out of the movement. But there was one rather unfortunate phase of this trend, and that was as each specialty developed the proponents seemed to drop the trauma part of whatever organ or area they proposed to treat. One could hear the remark made on every hand, "Oh, I don't treat fractures, I turn them over"; "I don't handle those things, I don't want to go into court"; "I don't want to get called out at night"; "the best way to treat a fracture is to send it to your worst enemy." In addition to this there arose another phase of the matter, namely, the Industrial Commissions and insurance companies became interested in these cases and this brought a little money into the picture. It was only a little money and entailed a great deal of additional paper work. In many instances an inferior type of practitioner began to grab the injured workmen, so that in some areas it became rather disgraceful to handle such cases. Treating cases of trauma was rather like practicing criminal law.

The net result of all this was that when World War I broke out the surgeons of the various countries were to some extent stymied with war wounds. They had not seen the horrible automobile accidents which we see

everyday, for most of these men had spent all their time doing elective operations and except for acute appendicitis and empyemas they worked largely with clean cases. There were plenty of men who could perform brilliant surgical operations up at the front at the casualty clearing stations but very few seemed to know how to handle these patients after they got back to the base. The result was that more and more hospitals in England and in France were getting more and more filled with people who were seriously injured and getting not very good care. Dr. Gilcreest knows this first hand from his experience in the Balkan area; I saw it when attached to the British Army and a good many others here saw it, too.

But there were men like Norman Kirk and Paul Hawley and others who stayed in the service and saw to it that when World War II broke out our Medical Corps had nothing to be ashamed of. And there were some others of us who back in civil life attempted to make surgery of trauma, which was increasing rapidly, interesting and decent.

Soon after World War I, Dr. John A. Caldwell formed a fracture service in the Cincinnati General Hospital, and Dr. Eslie Asbury and I formed one in the Good Smaritan Hospital in Cincinnati. Out of these two services many young house surgeons were trained in the practice of the surgery of trauma. The movement became so popular that now every hospital in and about our part of the country and a great many others, too, have such services.

So here we are today a group of surgeons gathered together for the purpose of studying the problems connected with trauma to the human body. I like to think of this as the fundamental of all surgery. After all, surgery began with the incision and drainage of pus, the amputation of the hopelessly diseased parts and the repair of injury. Many things have happened to eliminate pus. We just do not have as much of it as we did at one time. To go back a little, when I was house surgeon in 1919, I saw appendectomies at an average rate of ten a day and I cannot recall one clean case. Today one sees the appendix removed cleanly far more often than otherwise. Not so very many years ago radical mastoid operations were very common. There are many men today who have never seen such an operation. Sometimes we do not even operate for osteomyelitis. What has happened to infections may happen to hopelessly diseased parts in another way. Someday somebody will find something to do about cancer and it will probably not be a surgical operation. But there is left the repair of injury and that will go on as long as man goes on. An Association like this is settled for a long existence because it deals with the very fundamentals of surgery.

Now one more word which I wish to direct primarily to our new members. Come to meetings; get acquainted. Those of us who have been coming to this Association have got out of it a great deal more than just surgical knowledge. We have formed friendships and associations that will go on for life and these are some of the most valuable possessions one can acquire. You new Fellows would not have been selected to sit here with us if we did not expect that you would become one of us in every way. So as I said before, come to the meetings, come and read papers, come and carry on the traditions of The American Association for the Surgery of Trauma.

Original Articles

FURTHER STUDIES IN SKULL FRACTURES AND BRAIN INJURIES

HARRY E. MOCK, M.D.
Chicago, Illinois

THE purpose of this paper is to sum up the experiences of one who has ridden a surgical hobby for twenty-five years. For those who may be critical of a general surgeon's interest in this highly specialized trauma, it should be pointed out that this study began before the advent of neurosurgeons in Chicago.

During these twenty-five years this author has: (1) Studied almost all of the articles appearing in the literature under various titles of "Skull Fractures," "Brain Injuries," "Head Injuries," "Cranio-cerebral" or "Cerebro-cranial Injuries" and special subjects pertaining to these; (2) developed two survey sheets which have been used by himself, his associates and about twenty-five very altruistic and cooperative surgeons throughout the country in surveying the hospital records of consecutive patients with proved and practically proved skull fractures for five-year periods in twenty-six hospitals (in a few instances head injuries without fractures have been similarly surveyed) and (3) personally treated over 400 patients with proved and practically proved skull fractures and assisted in the treatment of 163 such patients seen in consultation.

In the same period he has treated 695 patients with head injuries without proof of fracture, patients who were unconscious or had some form of disturbed consciousness sufficiently serious to warrant at least six days of hospital observation and treatment. Another one-hundred consultations occurred for those patients with head injuries.

The keynote of this paper is what influences brain injury mortality rates and how may the same be reduced. The deductions herein set forth are based upon the experiences of other authors who have reported on consecutive cases with data concerning treatment and mortality rates, the studies of the management of consecutive cases in these twenty-six hospitals and their mortality rates as well as upon the author's personal experiences. (Table 1.)

TABLE 1

CONSECUTIVE SERIES CRANIOCEREBRAL INJURIES

A. Studied from literature 1900–1946	15,426
B. Studied from surveyed hospital records	
1. 1928–1935	3,156
2. 1935–1940	3,106
3. 8 small hospitals 1939–1945	282
C. Personally treated and seen in consultation:	
1. Skull fractures	584
2. Head injuries without fractures	695
Total	23,249

WHO MUST TREAT BRAIN INJURIES

Craniocerebral injuries occur wherever automobiles are driven, trains are run, airplanes are flown, power machines or horses are used or homes with stairways, bathtubs or waxed floors are built. The faster the wheels of industry turn and the greater the farm production becomes the more the number of brain injuries increase. Games and the pastimes of the young and old, kicks from domestic animals and conflicts between individuals add to the incidence. The victims of this trauma frequent our smallest as well as our largest hospitals. In fact, there are many small but well equipped hospitals located near extremely busy through highways or near industrial centers where the number of craniocerebral injuries treated far exceeds the number in certain of our well established neurosurgical centers. When we consider that the above potential etiologic factors are scattered all over the land it is evident that every hamlet, village and city will have their quota of craniocerebral injuries.

It is noteworthy that in approximately 6,500 cases collected from twenty-six hospitals, 34.6

per cent were treated by or had neurosurgeons available, while in 65.4 per cent there were no neurosurgeons handy for the management of the patients. This further demonstrates that brain injuries are largely the responsibility of the general surgeon.

Moreover, the majority of deaths from skull fractures and brain injuries occur in the first twenty four hours, depending upon the efficacy of the management. In the author's series of cases, 64 per cent of the total number of fatal cases died within the first twenty four hours, while 60 per cent of these first day deaths occurred in the first six hours following the injury. In the consecutive cases surveyed from twenty-six hospitals 47 to 60 per cent of their total deaths occurred in the first twenty-four hour period. Thus it is evident that the type of management rendered during the first twenty-four hours, and especially during the first six hours, spells life or death for many of these victims.

Given the wide distribution and the high preponderance of deaths in the first twenty-four hours it is axiomatic that:

(1) *A large proportion of brain injuries must be treated in hospitals far removed from the centers where neurosurgeons work.*

(2) *The full responsibility for reducing the mortality rate in the majority of instances rests upon the shoulders of the general physicians and surgeons who first see these patients.*

In the subsequent days certain intracranial conditions may develop which make the presence and aid of a specialist in brain injuries mandatory. It is here that the neurosurgeon enters the field. Constantly remember that during the acute stage *the specialist must go to the brain injury not the brain injury to the specialist.*

WHY SKULL FRACTURES?

Several years ago a neurosurgeon wrote the author as follows: "This continued talk about skull fractures is extremely irritating to a neurosurgeon who realizes that the brain is the important structure and not the skull."

We still contend that proved or practically proved (basal fractures altogether) skull fractures furnish the best common denominator for evaluating the comparative seriousness of any consecutive series of brain injuries. We all agree that it is not the skull fracture that is material, with the exception of depressed and compound fractures and certain linear fractures crossing branches of the middle meningeal artery or dural sinuses, but rather the amount of brain injury that determines life or death for the patient. No thoughtful surgeon absolutely ignores the skull fracture *per se.*

However, in reviewing many published articles on the subject of head injuries one finds:

1. Certain authors include all head injuries with a *history or evidence of unconsciousness* in their consecutive series of cases used to determine the mortality rate. Many include, while others eliminate, those head injuries which remain under observation in the hospital only twenty-four to forty-eight hours. Mortality rates published from such series vary from 4.5 to 10 per cent.
2. Certain authors include all head injuries which showed blood in the spinal fluid or had proved skull fractures. Their mortality rates vary from 17 to 21 per cent up to as high as 33 per cent. This classification involves practically a routine lumbar puncture, performed in the majority of cases as a diagnostic procedure but really for statistical purposes.
3. The author, reporting on proved or practically proved skull fractures in 421 cases treated personally, has a mortality rate of 16.8 per cent. If he adds those very serious head injuries, without proved skull fractures but with blood in the spinal fluid, his mortality rate jumps to 20 per cent, comparable to that shown by Wright, Fay and Rolette and Weiner, authors who included truly serious head injuries with their skull fractures.
4. However, if he adds the total number of head injuries treated by him since 1928 to his total number of skull fractures, the author has a series of 1,119 *head injury cases.* These 698 patients with head injuries without proof of skull fractures include only patients who showed unconsciousness and who were retained in the hospital for observation and treatment for at least six days or longer. The mortality rate in these head injury patients was 9 per cent, while the total mortality rate for the 1,119 skull

fracture-brain injury cases was 12 per cent.

Since, in the author's large series of collected cases secured from hospital records he had no opportunity of studying their consecutive run of head injuries without skull fractures, he, therefore, uses for comparison his and their series of proved or practically proved skull fractures. This gives the common measuring rod for comparison of methods of management and the varying mortality rates between all the hospitals studied. With few exceptions the presence of the skull fracture is no indication of the management needed.

TABLE II
SKULL FRACTURE GROUPS ACCORDING TO TREATMENT MORTALITY RATES IN EACH GROUP

Group	Treatment	Cases in Group, Per Cent	Deaths, Per Cent
I	Rest and observation only	5.5	0
II*	Simple medication, controlled dehydration	49.5	7.0
III†	Spinal drainage	36.0	29.0
IV	Operations	9.0	26.0
	Totals	421	16.8

* Includes 21 early deaths occurring before any treatment administered.
† 92% bloody spinal fluid.

HOW SERIOUS ARE SKULL FRACTURES?

Many serious head injuries with brain trauma do cause deaths even when a skull fracture is not present, but in every consecutive series of patients with truly serious head injuries without fractures studied from the literature, from the collected cases and from the author's personal series the mortality rates for head injuries varied from 5 to 15 per cent lower than for skull fractures.

In 1931, the author reported on his first consecutive series of one-hundred patients with proved and practically proved skull fractures. These were classified into four groups according to the treatment administered. The signs and symptoms which seemed to depict the underlying pathologic condition in each group were then analyzed to ascertain the *why* for the treatment given. He has continued this classification. It has furnished him increasing knowledge concerning those signs and symptoms which demand a given treatment. (Table II.)

From his 698 patients with serious head injuries without fractures the last 150 were analyzed and grouped as to treatment. (Table III.)

TABLE III
HEAD INJURIES—GROUPS ACCORDING TO TREATMENT MORTALITY RATES EACH GROUP

Group	Treatment	Cases in Group, Per Cent	Deaths, Per Cent
I	Rest and observation only	22.0	0
II	Simple medication, controlled dehydration	63.3	5.2
III*	Spinal drainage	14.0	27.2
IV	Operations	0	0
	Totals	150	7.3

* 45% showed blood in spinal fluid.

Tables II and III give another excellent example of the comparative seriousness of proved skull fractures and of head injuries without fractures. The more one dilutes his skull fracture series with head injury cases without fractures the lower his mortality rates decline.

Grading each skull fracture case record from each of the nineteen hospitals surveyed from 1935 to 1940, according to observation, interpretation of signs, symptoms and treatment administered, Mock and Mock, Jr. were able to classify these hospitals into good, average and poor management groups. Table IV shows the mortality rate in each hospital group.

HOW SERIOUS ARE VARIOUS TYPES OF FRACTURES

Three thousand one hundred ninety-four of the collected skull fracture cases from nineteen hospitals, including 300 of the author's, were studied to ascertain the location of the fracture. These were divided among the nineteen hospitals classified according to good, average and poor treatment. The death rate according to location of the fracture is shown (Table IV) it also gives the relative seriousness of vault, base and combined vault-base fractures.

It is evident that vault fractures give the

lowest mortality rates. Mortality rates as low as 4 to 9 per cent for simple vault fractures have been reported in the literature. The good (A to D) and average (E to I) hospital groups and the author's series confirm these assertions. In the poor management group, even though 50 per cent of their fractures were vault fractures, the mortality rate more than doubles that shown in any of the other groups. It was in this poor management group that the "do nothing" treatment and "watchful neglect" were chiefly practiced. The fact that it is a vault fracture does not limit active treatment.

TABLE IV

LOCATION OF FRACTURES AND DEATH RATE

Hospital, No. Cases	Total Death Rate, Per Cent	Vault, Per Cent	Death Rate, Per Cent	Base, Per Cent	Death Rate, Per Cent	Combined, Per Cent	Death Rate, Per Cent
Author's 300 cases	16.6	34.0	5.8	30.0	20.0	36.0	24.0
Hospitals A to D, 324 cases	19.7	50.9	9.0	24.7	38.0	24.7	20.0
Hospitals E to I, 1,822 cases	30.2	45.0	10.8	39.0	51.8	16.0	17.2
Hospitals J to S, 748 cases	33.2	50.0	22.7	25.0	62.5	23.6	25.4
Totals—3,194 cases	914 28%	1,384 43%	187 13.5%	986 30%	492 50%	666 20%	137 20.5%

In 7% location not stated.

Here we must depend upon the signs and symptoms of each individual patient to even approach a true diagnosis of the cerebral pathology.

The time-honored classification of concussion, contusion, laceration and hemorrhage still is sound. Unquestionably, there are thousands of cases of simple concussion, especially in children and young adults, occurring daily which never reach the hospitals and, therefore, are seldom included in statistical studies. Unquestionably, a variable degree of concussion, whether it is due to localized cellular changes, minute petechial hemorrhages or a commotio

TABLE V

COMPLICATED VAULT FRACTURES

Source	Total Cases	Death Rate	Depressed		Compound		Compound Depressed	
			Cases	Deaths, Per Cent	Cases	Deaths, Per Cent	Cases	Deaths, Per Cent
Author's	300	16.6	33(11%)	18	9(3%)	33.3	6(2%)	50.0
Hospitals A to D	324	19.7	25	20.0	2	100.0	4	50.0
Hospitals E to I	1,822	29.0	109	21.0	60	53.3	15	26.6
Hospitals J to S	748	33.2	85	31.7	55	38.2	13	53.8
8 Small hospitals	282	26.9	38	31.5	11	27.2	12	58.3
Totals	3,176	29.5	8%	26.0	4%	45.3	1.4%	45.4

From 3,176 hospital records surveyed the complicated vault fractures were studied to ascertain the relative seriousness of depressed, compound and compound depressed fractures. (Table v.)

With all the above described fractures, simple and complicated, the damage to the under-

cerebri, accompanies every contusion, laceration and hemorrhage case. Furthermore, every laceration and hemorrhage is accompanied by a certain amount of contusion to the brain and every hemorrhage must have some type of laceration. The classification of hemorrhage in regard to extradural, subdural, subarachnoid or cerebral can often be made by signs, symptoms or character of the spinal fluid. However, in many cases the hemorrhage is accompanied with such extensive contusion and lacerations that the diagnosis is made at the autopsy table. Finally, all of the above except concussion unquestionably are accompanied by variable degrees of localized or generalized edema. Even in concussion microscopic studies might reveal microscopic amounts of interstitial fluid.

From the standpoint of influence on the mortality rate, hemorrhages and lacerations rank first and contusions second. It is still a moot question whether simple concussion results in death. In our experience the cerebral laceration into the ventricle, giving almost pure blood in the spinal fluid, carries the highest mortality rate. The condition is suspected in life by doing the above mentioned spinal puncture. In several such patients treated by the author only one recovered. The tear into the ventricle was proved in six cases at autopsy.

MORTALITY RATE IN RELATION TO ETIOLOGY

The ratio of males to females with skull fractures in all the series studied showed approximately the same relationship, viz., 83 per cent males and 17 per cent females, with the death rate approximately 5 per cent higher among the males, suggesting the greater hazard of the causal factors.

The number of cases in each decade and the mortality rate for the given decade has been worked out in 3,184 cases. The relationship between the author's series and the good management series, as regards age decades and mortality rates, remains fairly uniform. The increasing mortality rates as we progress from average to poor management is quite dramatic.

Children survive skull fractures and brain injuries far better than adults. As a rule the treatment of these children need not be as drastic as it is in the older generations. In the earlier literature of this century, a hang-over from the teachings in the 1890's, one gains the impression that most surgeons believed "leave the skull fracture child alone and he will get well." As a result many serious brain injuries have received "watchful neglect." This tendency is reflected in the higher mortality rates in the average poor management and small hospital groups. While not occurring as often, certain children need spinal drainage the same as certain adults.

TABLE VI
AGE PERIOD

Age Period	Good to Above Average Treatment		Average to Poor Treatment	
	From % to % Cases	From % to % Deaths	From % to % Cases	From % to % Deaths
0–10 yr...	5 to 17	5 to 7	13 to 20	15 to 20
10–50 yr...	65 to 70	10 to 20	57 to 75	15 to 35
50–70 yr. or over.....	13 to 29	22 to 48	4 to 30	36 to 75

Fox and Blankstein,[1] in 1941, reported on 285 proved skull fracture cases in children treated in the Milwaukee Children's Hospital between the years 1922 and 1939. There were fifteen deaths in this series of 285 cases, a mortality rate of 5.26 per cent. They believe that the majority of children show marked shock from their craniocerebral injuries and require the most painstaking management during the early hours following injury. Forty-six and six-tenths per cent of their fifteen deaths occurred in the first twenty-four hours. Their results are comparable to the experiences of the author and the surgeons who treated the children in the good management hospitals. These facts set a goal for the poorer management groups when their children mortality rates mount to 20 per cent, the age decade most kindly responsive to treatment if given a chance.

A more detailed analysis of the age decades reveals that as treatment descends from a good to above average management, downward to an average to poor management, a marked increase in the mortality rates for each age period may be expected. (Table VI).

The cause of these brain injuries was studied in some 3,500 cases. The automobile caused from 36 to 50 per cent, the higher precentages coming from the metropolitan areas. Falls caused from 20 to 38 per cent; blows 12 to 21 per cent; trains and streetcars 2 to 8 per cent,

with numerous other causes accounting for a fraction of 1 per cent of the cases. The mortality rate was highest in streetcar injuries, then trains and finally automobiles.

MORTALITY RATES IN REGARDS TO SIGNS AND SYMPTOMS

Time will not permit a detailed analysis of the innumerable signs and symptoms and their varied combinations which follow in the wake of a traumatized brain. There are certain outstanding facts, however, which should be mentioned because of their marked influence on the mortality rate. It is from these facts, gathered from close observation of the patient, that prognosis concerning the outcome is made. A prognosis based upon the percentage of chance of recovery gives some comfort to the anxious relatives even though it is the proverbial "grasping at a straw."

Disturbed consciousness is, of course, the predominating symptom of brain injury. It was present in some form in 85 per cent of 2,685 collected cases when the signs and symptoms were recorded fairly carefully. This group had 844 deaths, or a mortality rate of 31 per cent.

Unconsciousness varies from a mild semiconscious condition to a deep loss of consciousness. It differs from coma in that there is an effort to respond to some spoken command, or in the absence of this, there still remains some definite response to pain stimuli, pinching of the arm or thigh causing the unconscious patient to move the part. In a coma there is neither sensory nor motor response. The disturbed consciousness may be modified or qualified by such descriptive terms as dazed, drowsy, stuporous or confused, noisy, delirious or a definite "lucid period." In surveying these hospital charts an attempt was made to tally the state of disturbed consciousness under the descriptive term used most frequently by the surgeon, or in some instances by the nurses, who recorded the same terms on the hospital record. This does not give an exact picture of each case but in a large series of cases it gives a fairly composite picture.

Unconsciousness, as described above was recorded in 30 per cent of this series of 2,685 cases and carried a mortality rate of 34.4 per cent; *coma* was recorded in 27 per cent of the cases and had a mortality rate of 65 per cent; *dazed, drowsy* and *stuporous* (seriousness increasing in that order) were recorded in 18 per cent of the cases and had a mortality rate of 22 per cent; *confused, noisy* and *delirious* were recorded in 7 per cent and the mortality rate was 23 per cent while *lucid interval* was described in 3 per cent of the cases and had a mortality rate of 25.5 per cent. This may well depict the extradural and sometimes the subdural hemorrhages which Munro and others claim are overlooked too frequently. Milder states of disturbed consciousness made up the other 15 per cent.

When the above states of disturbed consciousness are accompanied with focal signs, such as twitchings, paresis in an extremity, hemiplegia, convulsions, the deep and superficial reflexes sluggish, completely absent or frequently changing in character and especially if a Babinski sign is present, then the percentage of chances against the patient's recovery increases. His stock fluctuates, gradually goes up or quickly slumps, according to the intensity and persistence of these signs and symptoms. Of all these signs, persistent focal phenomena and complete absence of reflexes are far more serious tokens than are convulsions and frequently changing reflexes. Remember, that fixed pupils, constricted, dilated or irregular in size belong in the category of absent reflexes and offer grave indications of seriousness. The retention of urine or bladder and rectal incontenance belong in the same category. Other signs which facilitate one's estimate of the gravity of the situation are:

Slowed pulse and slow respiration which were two of the constant signs frequently mentioned by the old writers and which they considered bad prognostic signs if they persisted. Pulse rates of 40 to 60 and respirations of from 4 to 12 were recorded in many of the first twenty-four hour deaths. Unless pulse and respiration are recorded frequently, these signs are usually overlooked. This may account for the fact that some authors belittle their existence. When the slowed pulse and respiration are followed by a rapid and mounting pulse and respiration rate, one or both, or when the pulse becomes irregular and Cheyne-Stokes respirations develop, their prognostic implications are deeply enhanced; stabilization near normal is indicative of improvement. A persistently low diastolic pressure, 20 to 40 and even 60, is a grave indication. When accompanied with a high or a mounting systolic pressure, thus giving a mounting pulse pressure, the situation becomes more grave. To the author the blood pressure

is a far more sensitive indicator of medullary compression than are the pulse and respiration rates. Fifteen years ago, in a symposium on brain injuries, several speakers placed very little value on blood pressure information. In the recent literature practically all of the authors emphasized blood pressure information, especially the low diastolic and the increasing pulse pressure. This fact seems to confirm the author's views which he expressed first in 1931.

Edema of the lungs frequently accompanies these blood pressure and respiratory signs of gravity. In some cases it may be due to direct medullary compression but coming so early after injury as it often does it is more probably on a reflex vagus basis. Whatever its cause it is exceedingly dangerous to the life of the individual. Many a brain injury patient has literally drowned to death. Many have been saved by prompt postural drainage or aspiration.

Temperatures of 100 to 102°F. are present in a great majority of patients with true brain injury. Subnormal temperatures as low as 96°, and in one case 95°F., were recorded in many of the first few-hour deaths. The great majority of fatalities with early temperature readings over 103°F. die in the first twelve hours, thus indicating a very early disturbance of the heat regulating mechanism. In a lesser number of cases these high temperature readings may take two or more days to reach extreme heights. In children the temperature may sometimes go to 106°F. with recovery following. In only two instances has the author seen such temperatures in adults who recovered. In adults with damage to the heat mechanism any temperature reading of 103°F. or over warrants a grave prognosis, increasing in gravity with the rising temperature. In several patients the author witnessed temperatures of 108° and in two consultation cases it was recorded on rectal thermometers as high as 110°F. In one series of 1,347 cases, 614 gave sufficiently careful temperature records to warrant the following detailed analysis. (Table VII.)

Complications, that is, associated injuries and complicating diseases must be taken into account in evaluating mortality potentialities. In a previous publication the author showed the effect of associated injuries upon skull fracture brain injury mortality rates. (2) Suffice to say that the death rate increased from 4 to 11 per cent in the good to above average management cases and from 12 to 18 per cent in the poorly managed group when associated injuries were present.

A careful review of all these records indicates failure to observe the rules for treatment of shock, definitely enhanced by the associated injuries, scalp wounds sutured early, too many fractures immediately reduced, failure to use oxygen, especially in the presence of fractured ribs, and failure to recognize early and boldly attack the ruptured viscus. One of the deaths in the author's series occurred while the resident was suturing a scalp wound; another one might well be ascribed to too early and too active

TABLE VII
RECORDED TEMPERATURES IN 614 CASES

	Temperature	No. Cases	Deaths, Per Cent
During 1st 4 hr.	103–104	28	85.0
	104–105	12	83.0
	105–106	3	100.0
	106–108	2	100.0
During 4 to 12 hr.	103–104	29	86.0
	104–105	11	81.8
	105–106	12	100.0
	106–108	14	100.0
During 12 to 24 hr.	103–104	0	0.0
	104–105	0	0.0
	105–106	1	0.0
	106–108	4	75.0
During 24 to 48 hr.	103–104	6	66.6
	104–105	5	60.0
	105–106	9	88.8
	106–108	3	100.0
	108–109	1	100.0
During 2 to 4 da.	103–104	8	37.5
	104–105	3	66.6
	105–106	3	66.6
	106–109	4	100.0
Over 4 da.	103–104	11	36.0
	104–105	6	66.6
	105–106	8	25.0
	106–108	8	100.0
	109–110	1	100.0

Temperatures ranged from 100 to 103 degrees in 422 remaining cases with an average mortality rate of:

1st 4 hr	44.0%
4 to 12 hr	40.0%
12 to 24 hr	13.5%
24 to 48 hr	21.0%
2 days or more	25.0%

treatment of the compound fracture; another one was probably due to overlooking the ruptured spleen, although five other patients with ruptured spleens and one with a ruptured liver were recognized, operated upon at once and all but one saved. Several patients with skull fractures complicated by fractured ribs died in the earlier years of the author's experience who today conceivably might be saved by the use of oxygen, postural drainage and aspiration of the accompanying pulmonary edema.

Meningitis is the bugaboo of skull fractures, especially fractures through the paranasal sinuses. In fact, operations for repair of the dura in the presence of cerebral spinal fluid leakage have been strongly advocated to prevent meningitis, even though the operation itself carries a high mortality rate. The author has a meningitis rate of occurrence of 1.5 per cent in his personal cases and 3 per cent when his consultations are included. Voris has reported on a series of cases showing the meningitis rate around 1 per cent. In the collected series of cases from the twenty-six hospitals the meningitis rate varied from .2 to 2.5 per cent. Meningitis should be reduced in these days of the sulfonamides, penicillin and streptomycin. However, future authors in reporting their results with these drugs in brain injuries, should bear in mind that the meningitis rate following cerebral trauma under old management was always exceedingly low.

Pneumonitis in its various forms is the most dangerous complication recorded in skull fractures. Here the new drug therapy, and especially the increasing use of oxygen and the early and more frequent postural changes in the patient, will undoubtedly reduce the incidence of this grave complication.

MORTALITY RATE INFLUENCED BY MANAGEMENT

There are many general principles of management of skull fractures and brain injuries concerning which we are all more or less agreed. There are certain special rules of procedure governing the treatment of these injuries concerning which there is still entirely too much controversy. The controversies have influenced many a surgeon, seeing only the occasional brain injury case, to use a "do nothing" treatment, a "do too much" treatment or a form of management that is summed up by a slogan becoming quite popular today, "watchful neglect." In other words, viewing brain injuries as a nationwide problem these controversies have increased the mortality rate far more than we realize. One cannot talk to numerous county medical societies, hospital staff meetings and other small groups without having these impressions driven home. One cannot see many patients in consultation and hear the attending surgeon explain why he did or did not do this or that (quoting various authors) without realizing that too many patients were jeopardized because of controversies among those who should know the correct answers.

In a previous paper by Mock and Mock, Jr. in 1942,[3] a detailed study of the signs and symptoms present in each of the four treatment groups was made. The author has brought his group classification up to date for his entire 421 cases and added this to the chart previously published showing the groupings for the good, average and poor management in 3,106 cases from nineteen hospitals. (Table VIII.)

In a review of fifty-nine articles published since 1939, concerning all types of craniocerebral injuries, thirty-four dealt with general management, twenty with operative treatment and the remainder with related problems. Nine of the papers dealing with operations also referred to spinal drainage and/or dehydration. Thus in a total of fourty-three articles the authors favored carefully controlled dehydration in thirty-four, were opposed to it in two and did not mention it in seven. In these forty-three articles spinal drainage was strongly favored by thirty-six of the authors. Six used it but indicated a lukewarm attitude toward the procedure. In only one of the articles was spinal drainage completely condemned. This condemnation came from Cutler and Whitfield[4] who reported on a series of patients with 396 head injuries with a gross mortality rate of 11.8 per cent. They divide their cases into mild, moderate and severe groups. "44 per cent were mildly injured, and were unconscious less than 15 minutes . . . mortality rate 1.5%." Using their percentages and combining only their moderate and severe groups (60 per cent of the total) one finds a mortality rate of 19 per cent. They state that spinal drainage is "only mentioned to decry it." They further state it was used in only 3 per cent of their patients and has "now been abandoned because of one death ascribed to the procedure." This would indicate a very limited experience with spinal drainage. Comparing their mortality rate of

19 per cent with the death rates (17 to 21 per cent in proved skull fractures) in the four good treatment hospitals where spinal drainage was performed in 50 per cent of their cases, one is forced to conjecture concerning the soundness of their condemnation. Remember further that their series were not proved skull fractures but compare more with our series of severe head injuries with a mortality rate of 12 per cent.

TABLE VIII

COMPARATIVE RESULTS OF GOOD, AVERAGE AND POOR MANAGEMENT

Hospital	No. of Cases	Group 1. Rest only	Group 2. Dehydration	Group 3. Spinal Puncture	Group 4. Operation	Gross Death Rate
Author.....	421	5.5%	49.5%	36.0%	9.0%	16.8%
Good, A to D....	323	2% to 18% Average 8.0%	11% to 62% Average 36.0%	18% to 60% Average 50.0%	4% to 7% Average 5.8%	17.0% to 21.0%
Average E to I...	2,033	5% to 18% Average 11%	42% to 76% Average 50%	14% to 39% Average 28.3%	4% to 25% Average 10%	23.0% to 29.0%
Poor, J to S.....	750	5% to 32% Average 16%	10% to 72% Average 51%	10% to 44% Average 23%	5% to 20% Average 9.5%	30.0% to 42.0%

About twelve years ago this author submitted a questionnaire to fifteen neurosurgeons. He ascertained that thirteen of the fifteen favored spinal drainage. The late Dr. Dandy and Dr. Sachs alone were opposed to it. A few authors, writing on the subject since then, have quoted Dr. Dandy as their reason for a lukewarm attitude toward the procedure. Cutler and Whitfield are the only authors to our knowledge who have joined the other two in absolute condemnation. In our opinion, the fact that "90 per cent or more of the profession" (Dandy[5]) continue to use dehydration and spinal drainage is the strongest testimony in favor of their values in management. Furthermore, the fact that 90 per cent of the authors writing on this subject today strongly favor spinal drainage is equally conclusive evidence of its value. The opponents of the method have published few mortality rates. Therefore, we must turn to published statistics and the analysis of large series of collected cases that deal with both treatment and mortality rates, in order to substantiate the claims of those who favor and to refute the statements of those who oppose dehydration and spinal drainage.

Debydration. One notes in the literature a tendency to limit dehydration to the limitation of fluids and the use of magnesium sulfate per rectum, through a Levine tube or by mouth. The great majority of these authors are strong advocates of the early use of spinal drainage after shock has been overcome. The author is still confident that 50 per cent glucose used only when signs and symptoms indicate dangerous possibilities will meet the crisis and obviate the need for so many lumbar punctures. However, if either of the two methods are to be neglected, he would favor less hypertonic solutions and more lumbar punctures. The use of magnesium sulfate administered intravenously and even sucrose carry more elements of danger than do hypertonic glucose solutions, therefore, the author is opposed to the former. From a clinical standpoint there is overwhelming evidence of the value of dehydration when carefully controlled and not used blindly or excessively to the point when the fluid balance of the body is dangerously deranged. Attention is again called to the fact that hypertonic plasma solutions, as used by the British during the war, may prove the safest and best hypertonic solution, when and if it ever becomes sufficiently available.

Spinal Drainage. If the general rule of close observation and frequent examinations is followed one will note sufficiently early those *signs* and *symptoms* which so strongly indicate the need for lumbar puncture and spinal drainage. The correct interpretation of these signs and symptoms early in this game of saving a life indicates the expertness of the player far more than his aptitude in inserting the spinal puncture needle. The dependence on and the correct interpretation of signs and symptoms will obviate the old teaching, seldom heard now, of routine lumbar punctures.

The nightmare of a herniated medulla ob-

longata through the foramen magnum has been impressed so vehemently upon the minds of the profession by a few opponents of lumbar puncture that the judgment of many has been warped. This fear has caused some to delay the spinal drainage forty-eight, seventy-two or more hours until the patient is moribund. Then as a last resort puncture is performed. The ensuing death is either blamed on the lumbar pucture or, in reporting the given case, the surgeon states that the procedure did no good.

Delaying lumbar puncture when the signs and symptoms indicate its need is just as reprehensible as to delay operation for an early, very acute appendicitis. In witnessing a great many autopsies due to brain trauma this author has never seen a herniated brain stem that could be ascribed to the lumbar puncture. He has seen at least eight cases when the hemorrhagic, edematous brain, due to its own weight, has sagged downward into the only natural opening that permits expansion, viz., the foramen magnum. Such brains have a ring of edema and congestion comparable to the distal protion of a limb encased in a tight plaster cast. Every surgeon should fear the natural laws of weight and gravity in the instance of a water-logged brain far more than herniation of the brain from spinal drainage.

When indicated, the earlier spinal drainage is performed the more life-saving it becomes. The earliest possible relief of generalized cerebral edema, with its accompanying suppressed circulation and anoxia, is the aim of treatment. Spinal drainage of a sufficient amount of fluid, usually bloody, to make more room for the entrance of arterial and the escape of venous blood is the only method left unless we wish to return to the days of subtemporal decompression. Table IX, developed from the author's and the collected series of cases, representing good, average and poor management hospitals, shows that in the lowest mortality rates spinal drainage was used frequently and early during the first twenty-four hours. It also exemplifies the value of true drainage, regardless of the manometer reading, as compared with the removal of a small amount of fluid. How easy it would be for the surgeons who used the procedure in only 19 per cent of their cases, and used it late, to say spinal drainage was of scant value.

TABLE IX

SPINAL DRAINAGE IN FIVE HOSPITALS

Time and Amount of Drainage and Mortality Rates

Source	No. of Cases	Gross Death, Rate, Per Cent	Lumbar Punctures, Per Cent	Punctures First 24 Hr., Per Cent	Average Amount Fluid Drained	Death Rate in Group 3, Per Cent
Author's	421	16.8	36.0	84	40 cc.	29
Hospitals A and B	184	18.5	70.0	80	40 cc.	21
Hospital H	1,342	28.4	32.0	60	28 cc.	37
Hospitals R and S	112	41.0	19.0	20	7 cc.	78

The strongest evidence of the value of spinal drainage is found in the article by Rowlette and Weiner,[6] written in 1941, and previously quoted by Mock and Mock, Jr. Their experiment consisted in assigning, in rotation, every patient with a skull fracture and a truly serious brain injury to two services in the St. Louis City Hospital for treatment. Unit A continued to treat these patients by no limitation of fluid, a very moderate dehydration and only an occasional spinal puncture. Unit B adopted the most radical dehydration for forty-eight hours and almost routine, early lumbar punctures with practically total drainage of all the spinal fluid at each tap, "as recommended by Fay." The mortality rate after three years for unit A was 37.3 per cent and for unit B 21 per cent. This article is recommended to those who still doubt the value of spinal drainage.

Group IV., the operative group, represents one of the great battle grounds of surgery. In 1896, Senn, in an unpublished article found in the Crerar Library, cried out against the almost routine practice of trephining skull fractures or suspected skull fractures. The early years of 1900 reveal authors writing about conservative management as opposed to trephining. In 1906,

Cushing wrote his memorable article on subtemporal decompressions in the presence of bursting types of fractures of the skull. This not only stimulated early x-ray of every head injury, the x-ray being a new and rather mysterious adjunct to surgery, but it revived operative treatment. In some clinics subtemporal decompression became more routine than spinal drainage is today. The mortality rates, which were already very high, climbed.

In 1920, Sharpe[7] wrote his book on "Diagnosis and Treatment of Brain Injuries." He gave a survey of hospital records showing that in six New York hospitals mortality rates for the decade prior to his publication ranged from 45 to 65 per cent in brain injury cases, "usually with skull fractures." He was a strong advocate of subtemporal decompression and showed the mortality rate lowered to 33 per cent by his methods.

Until 1930, there were the strong advocates of surgery and those just as strongly opposed to it. The latter turned to other methods, notably dehydration and spinal drainage. Dehydration was a new procedure and was undoubtedly overworked. The advocates of lumbar puncture became almost fanatical in demanding routine punctures in every patient with a head injury plus unconsciousness. Until the present time, controversy concerning surgery has continued to rage but to an ever decreasing extent. The great majority believe in and practice spinal drainage when indicated and believe in surgery for very definite indications. Conditions needing operations are depressed skull fracture, but not all slightly depressed fractures; compound fracture, practically all showing some depression; extradural hemorrhage; subdural hemorrhage and or subdural collection of fluid and conditions requiring subtemporal decompression or exploratory decompression; encephalography and plastic repair of the skull.

Even today there are those who advocate a much higher precentage of operations than is true with the average surgeon treating these injuries. The refinements growing out of their extensive experiences have greatly benefited brain surgery. However, we believe that operative rates over 10 to 12 per cent in the hands of the average surgeon is a trend toward radicalism and will increase mortality rates. Already the surgical profession has developed principles covering *when, where* and *how* to operate these cerebral injuries that were little recognized in the early decade of this century. A few of these which have very definitely lowered mortality rates may be stated tersely as follows:

1. Early operations for skull fracture brain injuries are usually fatal.

2. The early subtemporal decompression is a thing of the past. This operation is seldom recommended today.

3. Compound fractures, especially those with visibly damaged dura and brain, require early and thorough débridement but must wait until the shock has subsided and the condition of the patient warrants the procedure.

4. Depressed fractures must be elevated but many a mild depressed fracture outside the motor areas recover and do well without operation. In the presence of a depressed fracture focal signs suggesting an underlying extradural and perhaps a subdural hemorrhage warrant operation as soon as its benefits outweight its dangers to the patient. Otherwise, most depressed fractures can wait days before they are attacked surgically.

5. Extradural hemorrhages have a classical picture and should be operated upon when diagnosed. In this author's experience the signs and symptoms of extradural hemorrhage seldom develop in the early hours, they more often develop after twelve to twenty-four hours. When diagnosed operation must be done as an emergency procedure.

6. The acute subdural hemorrhage is still a controversial subject. Munro[8] and his followers believe that it occurs more often than is recognized and advocate early exploration, although not until the patient's condition warrants the procedure. Voris[9] and others believe that the risk of early operation of these acute subdurals is greater than to delay. By waiting, some of the suspected cases clear up either due to wrong diagnosis or because the hemorrhage was small and was absorbed. The others will wall off and can be attacked later as chronic subdurals. Practically all agree that this condition warrants sooner or later small exploratory craniotomy openings, usually bilateral.

7. General anesthesia is tolerated poorly by the acute brain injury patient. Local anesthesia can and should be used whenever possible.

To offset the war influence for more surgical management of brain injuries the author reproduces Table XA first published by him in 1931, and adds Table XB, to bring the skull fracture operative story of this century up to

TABLE XA
OPERATIONS AND MORTALITY RATES
From the Literature 1900–1930

Years	Total No. of Cases	Gross Mortality, Per Cent	Operative Data		Operations: Cases Under B Only		Operative Mortality, Per Cent	Comment
			A No Data; No. of Cases	B No. of Cases with Data on Treatment	Number	Per Cent		
1900–1910.....	1,700	46.6	922	778	93	12.0	59.0	About 50% were basal sk. frs.
1910–1920.....	2,850	49.7	1,000	1,850	449	24.2	45.6	Many patients were operated for subtemporal decompression only
1920–1928.....	4,099	33.4	90	4,009	587	16.0	46.6	Subtemporal decompressions still predominate
1926–1928.....	2,085	25.8	90	1,995	216	10.8	50.0	Tendency for more definite reasons for operation
1930, Author's cases	100	20.0	0	100	13	13.0	30.8	Skull fractures only
	10,834			8,732				

TABLE XB
OPERATIONS AND MORTALITY RATES
From the Literature 1930–1947

Years	Total No. of Cases	Gross Mortality, Per Cent	Operative Data		Operations: Cases Under B Only		Operative Mortality, Per Cent	Comment
			A No Data No. of Cases	B No. of Cases with Data on Treatment	Number	Per Cent		
Swift—1932.....	190	26.0	0*	190	15	8.0	56.8	Serious head injuries and sk. frs.
Gurdjian—1933...	718	19.0	243	474	51	10.7	37.0	The 475 cases were proved sk. frs. with death rate 25%
Fay—1935.....	363	17.8	0	363	11	3.0	81.8	Serious head injuries, 23% sk. frs.
Furlow and Sachs—1935.	192	23.0	0	192	96	50.0	33.3	16 (Class I.) operated early—16 deaths
Munro—1938.....	1,203	20.7	0	1,203	444	36.9	32.4	Craniocerebral injuries
Meredith—1940...	391	17.0	0	391	42	10.7	23.8	32% of these were sk. frs.
Author.....	331	16.8	0	331	36	10.8	27.7	Proved sk. frs.
	3,388			3,145				

* 53 articles failed to mention any consecutive series of cases or any specific data on treatment.

date. It graphically portrays the earlier high mortality rates, the reduction in the same and especially the corresponding reduction in operative frequency and operative death rates.

CONCLUSIONS

1. Proved or practically proved skull fractures are used in this article as a common denominator for comparison of reported and collected cases. Head injuries of varying degrees of seriousness will so dilute skull fractures and truly serious brain injury mortality rates that an unfair basis of comparison results.

2. Brain injuries and the few complicated skull fractures are used in evaluating the signs, symptoms and the treatment used. Emphasis is placed on the brain injury as the causal factor of death.

3. The cause of the injury, sex and age of the patients, as well as the location and types of skull fractures, are set forth in the collected cases to show that these are quite comparable and, therefore, do not influence the higher mortality rates in one series as compared with another.

4. With the wide distribution of brain injuries, the fact that 65 per cent occurred and were treated in communities where neurosurgeons were not available and with from 45 to 64 per cent of the deaths occurring in the first twenty-four hours, it is self-evident that this is chiefly a problem for the general surgeon.

5. The signs and symptoms indicate the type of treatment and can be so evaluated as to be of real prognostic value. Very close observation is necessary as these signs and symptoms change complexion both quickly and insidiously.

6. The mortality rates are either as low as 17 to 20 per cent, as reported by a few authors and as shown by the good management hospital group, or as high as 30 to 42 per cent, as reported in the literature and as shown by the poor management hospital group, depending upon the surgeon's judgment and ability to institute carefully controlled dehydration, early spinal drainage when indicated and operation only when the time and very definite indications warrant the procedure.

7. Failure to use the methods, fear of them engendered by controversy, failure to apply them early instead of waiting until the patient is approaching death and failure to observe proved principles concerning operations accounts for 10 to 25 per cent of the brain injury deaths throughout the nation. This is a challenge to every surgeon.

8. The "neglect" in the doctrine of "watchful neglect" too often applies to both observation and treatment.

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DISCUSSION

John Raaf (Portland Ore.): Dr. Mock has collected a tremendous number of cases of craniocerebral injury and I agree with him regarding most of the conclusions he has drawn from this vast experience.

Certainly, the treatment of shock is of first importance. I have in mind the case of a teen-aged boy who received a head injury and remained in profound shock over a period of five or six hours. Finally, intravenous fluids were administered and he began to improve. Later he developed urinary suppression without any evidence of gross kidney damage and finally died with a mounting blood urea. It was thought that the profound prolonged shock was responsible for the urinary suppression.

I agree that children survive craniocerebral injury better than adults. I have been impressed how often a child who has sustained a head injury will present the picture of having an extradural hematoma, in that an hour or so following the blow on the head he will begin to vomit and become drowsy. There may or may not be localizing signs. I have been on the verge of operating to evacuate the hematoma, which I thought was present, but a little further delay has resulted in the child regaining consciousness and subsequently recovering completely without surgery. No doubt edema of the

brain in these children accounts for this picture. Fine judgment is required in such cases for certainly one does not wish to overlook an extradural or acute subdural hematoma.

Dr. Mock made one statement with which I am not in full accord, namely, "Constantly remember that during the acute state the specialist must go to the brain injury, not the brain injury to the specialist." Perhaps the disagreement hinges on the definition of the word "acute." I agree that if the patient is in profound shock he should not be moved. However, in the case of an extradural or acute subdural hematoma, I believe that it is very important to move the patient as rapidly as possible to a wel equipped hospital where he can be operated upon and receive adequate postoperative care. In my opinion, an extradural hematoma is an extreme surgical emergency. I have seen perhaps five or six patients die of extradural hematoma within twelve hours after injury. Ten years ago when I was called regarding a patient whose history sounded as if he had an extradural hematoma, I would pack my surgical equipment and go to some neighboring town to operate. For two reasons I have come to the conclusion that this was wrong: First, the operation can be started more quickly if the patient is brought to the surgeon and sometimes an hour or so means the difference between life and death; second, the postoperative care of the patient who has had an extradural hematoma is extremely important and should be supervised by the surgeon who has performed the operation. A number of times it has been necessary to reopen heads in which the extradural hematomas have reaccumulated. Had these patients not been under my direct supervision (and this happened in one instance) they would have lost their lives from the recurrence of the hematoma.

There is one other point regarding extradural hematoma which I would like to make. I believe that one, two or even three burr holes may not be enough to disclose the hematoma. I usually place four burr holes, at least on the suspected side, before I am satisfied that no hematoma is present. The following two cases are illustrative:

Case I. An eighteen year old boy was thrown from a horse. The fourth burr hole high in the parietal area near the midline finally uncovered the extradural hematoma which had stripped the superior longitudinal sinus away from the bone and extended over to the opposite side of the head.

Case II. An eleven year old boy, while riding a bicycle, was struck by an automobile. The extradural hematoma in this instance was far forward over the left frontal pole.

Neither the hematoma in Case I nor in Case II was small, and in my opinion, had these hematomas not been discovered and evacuated the patients would not have survived.

I agree with Dr. Mock that there are numerous signs and symptoms which will indicate whether the patient is getting better or worse. To my way of thinking the two best indicators are the depth of the coma and the height of the temperature. Deepening coma and rising temperature are alarming signs.

In closing, I would like to say that I am in complete accord with Dr. Mock's opinion regarding spinal drainage.

Joseph E. J. King (New York, N. Y.): I want to thank Dr. Mock for his splendid paper and for his courtesy in sending me a copy of it. I have read it several times and enjoyed each reading.

The outstanding feature seems to me to be his approach to the subject by what we call common sense or horse sense, which is the best kind of sense in the world anyway. His teaching should be widespread because head injuries themselves are very widespread and distributed. There are not enough neurosurgeons in the United States to look after all these patients, therefore, the general surgeon must take care of many of them or most of them.

In order to do so they must be acquainted with these conditions and how to manage them, just as well as they know gastric, thyroid and other phases of general surgery. Dr. Mock's paper, if studied properly, will be of great help to anyone in the proper handling of these conditions.

I am glad he placed such emphasis on the therapeutic value of the lumbar puncture properly done. Lumbar puncture *per se* never hurt anyone. It is the removal of fluid in the wrong patients that produces the fatality. There is no place here for the discussion of the various kinds of operative procedures, so I shall say nothing about any kind of operation.

I should like to emphasize the apparent difficulty of making the diagnosis of acute and chronic subdural hematoma. The correct diagnosis is sometimes quite difficult to make. I should like to recall two instances of fine, high-powered medical friends of ours, both from Virginia. One of them lay around for three months with a subdural hematoma. His mentality was quite poor. They were going to ship him off to Florida or Arizona to get rid of him. Finally they made a diagnosis of left frontal lobe tumor. A little burr hole, as John Raaf spoke of, let out a lot of bloody water. Now he is going along quite well and is the author of one of our very fine books on medicine. That man was in the hands of some of the biggest doctors we have. The unanimous opinion was that none of them knew what was the matter with him until finally, after I was requested to see him, a burr hole was made posteriorly on the *right* side and a large amount of bloody fluid was evacuated. It was not of recent origin. The physician-patient, who was in a deep stupor, regained his consciousness in a few minutes after evacuation of the bloody fluid and inquired about

the membranes of the hematoma, condition of the convolutions, etc.

The other case was that of one of our distinguished colleagues who was in the same hands for three weeks. The nurse said that he could raise his right hand at times and at other times he could not. He had a large dilated pupil on the same side, the right side. I learned about his illness just before he died and went in and stood around with two other friends until he died. He was then moribund and had Cheynes-Stokes respiration. Autopsy showed a huge, right-sided subdural hematoma about 1 inch thick from stem to stern and shaped something like a turtle's back. The diagnosis that had been made of that doctor's condition until the time of his death—for three weeks in the hands of all these big doctors—was written in the clinical record, upon which all of them agreed. That diagnosis was, "Allergy of the brain due to eating wheat muffins."

Harry E. Mock (closing): I have nothing further to say, except to thank the discussers.

THE SYMPATHETIC REFLEX ARC AND ITS CLINICAL SIGNIFICANCE

ANATOLE KOLODNY, M.D.
New York, New York

SURGEONS know that a blood vessel responds to irritation by local contraction, and they have long suspected that injury to an artery of an extremity initiates a sympathetic reflex which puts the collaterals of the limb into spasm. Anatomists and physiologists, however, have been unable to demonstrate such a mechanism. They would not admit the presence of a receptor sympathetic system in blood vessels. Clinicians, therefore, have been reluctant to accept the presence of a reflex sympathetic action. In the growing literature on vascular spasm, one finds reports aiming to prove that the sympathetic plays no rôle whatsoever in arterial spasm, while other instances are reported to prove that the sympathetic is the responsible transmitter of the spasm to the collaterals. Such a discrepancy is due to different interpretation of clinical phenomena in the absence of incontrovertible anatomic and physiologic facts. While some anatomists (Stohr, Dolgo-Saburoff) claim to have identified an intramural nervous apparatus with ganglion cells in the vessel wall, others (Woolland) could not find them. Le Gros Clark is certain that they do not exist; he claims that ordinary connective tissue cells have been mistaken for ganglion cells. While Leriche[1] states that vascular trauma initiates a local reflex by way of a special intrinsic mechanism, Cohen,[2] in his Hunterian lecture states: "An afferent arc for any reflex via the sympathetic ganglia has not yet been found."

Our interpretation of the word "reflex" is conditioned by our knowledge of tendon and skin reflexes, as an immediate response to a stimulus with an immediate termination of the response at the end of the stimulation. The sympathetic reflex is not the usual kind; it is active for hours or even days after the reflex arc is broken, provided that the reflex has been set in motion repeatedly over a period of time. We must consider the presence of a self sustaining element in a sympathetic reflex. Even an ankle clonus does not always terminate the instant the stimulus ends. When a reflex focus of irritation becomes well established even after the original exciting cause—the trigger—has disappeared, it is known as a reflex sympathetic dystrophy. This reflex dystrophy may be expressed by one or more characteristics of sympathetic disturbance, such as pallor, cyanosis, sweating, edema, atrophy of the skin or the so-called osteoporosis. Only interruption of the reflex arc by blocking segments of the sympathetic pathways may give relief in early cases.

Arterial spasm is known to have followed fractures of long bones when the main artery is irritated to a greater or lesser extent. You have all observed the absence of the pulse in the extremity for as long as an hour or more following manipulation of a fracture of long bones. The classical example of arterial spasm is the so-called Volkmann's ischemic contracture. We all know that the Volkmann lesion occasionally follows injuries of soft parts when no fracture is present. This lesion has also been observed after prolonged application of a tourniquet. As long ago as 1877 Esmarch suggested constrictors of soft rubber stating that the inelastic constrictor frequently caused gangrene of the extremity. That Volkmann's original theory that the lesion is due to tight splints is erroneous is well known. Cases of Volkmann's contracture have been seen when no splints were applied or any other external pressure exerted. Even simple embolectomy of the brachial artery is occasionally followed by a Volkmann lesion. We also know that nerve injury is not indispensable for the development of a Volkmann contracture. Experienced surgeons believed all along that spasm of the artery and reflex spasm of the collaterals are responsible for the Volkmann contracture, and only the arguments of anatomists and physiologists that there is no such a spasm militated against a general acceptance of this view. Barnes and Truetta[3] have actually demonstrated in animals the spasm that followed tight application of a tourniquet. They even showed a segmental spasm of the main artery

of the opposite limb. However, because of the obvious reduction of arterial blood supply after application of a tourniquet, their experiments with arterial spasm are not entirely convincing.

Using rabbits in my experiments I proved that an irritation of a main artery causes immediate contraction of the collaterals—the small arteries and arterioles. After the hair of the ear of a white rabbit is removed, the ear is fastened to a window on a board. A strong transmitted light permits easy observation of the change in caliber of the small vessels in the ear. When the common carotid artery of the same side is exposed and teased with forceps, it contracts immediately and at once the small arteries in the ear follow suit. When the irritation of the carotid ceases, the artery remains contracted for about ten minutes and then resumes its normal caliber. The arterioles of the ear dilate soon afterward. Thus, there is no doubt that vascular trauma initiates a local reflex spasm of the small arteries and arterioles.

We all know of numerous clinical observations which have defied rational scientific explanation. For instance, why do some patients faint when the pleura is punctured in thoracocentesis, or when a constrictor is applied to the arm preliminary to veni-puncture? Why does hyperventilation induce a fit in the epileptic? Why does the voice rise in pitch in anger? Slowing of the pulse, extreme pallor, profuse sweating accompanying the fainting in thoracocentesis and veni-puncture suggest cerebral anemia—vasoconstriction of cortical blood vessels. We know that a single deep inspiration causes arterial constriction; hyperventilation then causes constriction or spasm of the cortical blood vessels, thus precipitating a fit in the epileptic. The interrelationship between the cerebral and peripheral vasospasm explains the high pitch of voice in the angry; the blood vessels of the vocal cords contract causing the cords to shrink thus causing a higher pitch. All this reasoning assumes a sympathetic reflex arc extending to the cerebrum. To prove the presence of such a reflex arc I made use of the encephalograph.

Since to many electro-encephalography is an unfamiliar field, by way of introduction suffice it to say that just as electrocardiography records the electric potentials of the heart so does electro-encephalography record the electric impulse of the brain cortex. However, the electric discharges of the brain have a very low voltage, about one-hundredth of the voltage in electrocardiography. There are three leading frequencies in brain waves; the alpha or medium wave, between 6 and 13 per second; the beta or fast wave, between 14 and 60 per second, and the delta or slow wave, between 1 and 5 per second. The typical electro-encephalogram of the normal adult shows about 9 to 10 waves per second, with an amplitude or voltage of 10 to 50 microvolts. Slow waves with a wide amplitude—delta waves—are registered over areas where the cerebral cortex is compressed by an expanding lesion or where there is some other interference with the blood supply of the cortex, as in cases with an embolus in the middle cerebral artery. Induced constriction of the vascular bed in the cortex, therefore, will be reflected in slow, delta waves. If the blood supply of the cortex is totally defective, all electrical activity stops and the brain waves flatten.

When during a routine encephalography veni-puncture of the right antecubital vein was performed, it elicited irregular activity from the right frontal lobe, characterized by ragged high voltage waves, superimposed upon low voltage beta waves. The removal of the needle from the vein caused immediate return to the normal activity. During this experiment no alteration of activity from the left frontal lobe was elicited. (Fig. 1.)

Another experiment concerned a woman with cerebral arteriosclerotic manifestations. Tracings of the right and left parietal leads were made. A medium voltage fast activity was obtained from the left parietal lead and 10 to 20 per second low voltage activity in the right parietal lead. A tourniquet was then applied to the right arm. At once the waves from the right parietal lead became much slower and the amplitude much wider. Upon removal of the constrictor a return to the dominant rhythm was obtained. (Fig. 2.) A tourniquet was then applied to the left arm and immediately slow waves with wide amplitude were obtained from the left and to a lesser extent from the right parietal leads. The introduction of a needle in the cubital vein gave no added change in abnormality. As soon as the tourniquet was removed, an immediate return to the dominant rhythm was obtained. (Fig. 3.)

This immediate response of the vascular supply of the cerebral cortex to induced vasoconstriction in the arm is definite proof of the

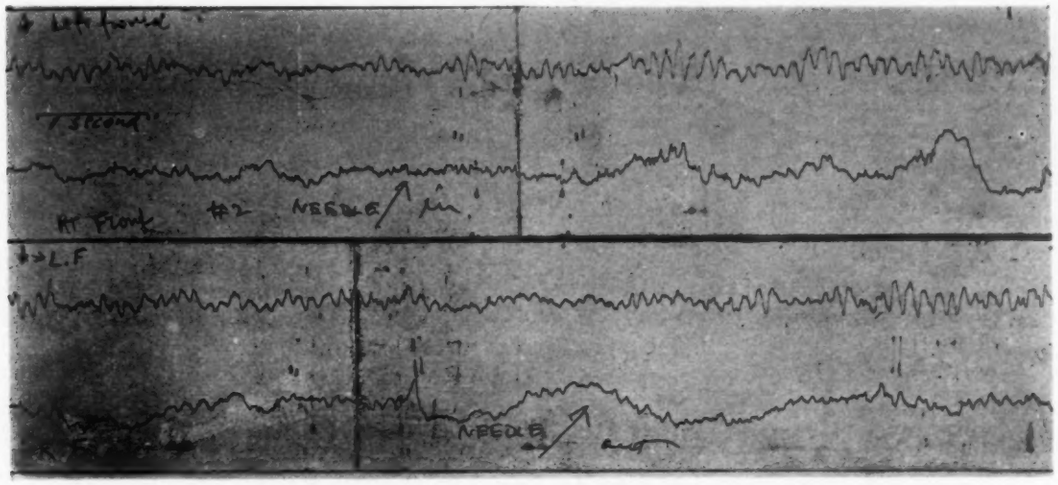

Fig. 1.

presence of an afferent reflex receptor in the vessel wall of the arm. Puncture of the cubital vein causes a local spasm of the vessel and an immediate reflex constriction of the cortical vessels; the application of a tourniquet to the arm, which results in a vascular spasm of the numerous blood vessels in the arm, leads to a pronounced spasm of the cortical vessels not only on the ipsolateral side but bilaterally. In the light of these facts, it is possible to explain an old observation of Galen in the second century A.D. that in local epilepsy, clonus spasms may be arrested by tying a band round the limb in which they start.

It is known that stimulation of the cerebral cortex causes a diminished cutaneous temperature on the contralateral side of the body and that the side of the body feels warmer to touch after the removal of the contralateral motor-sensory area of one hemisphere. Our encephalograms show that there is also present a reverse reaction from the periphery to the center. Since spasm originating in the limb is at once reflected into a vascular spasm in the cerebrum and a spasm there leads to a spasm elsewhere in the body, it follows that a vascular spasm anywhere in the body sets off a chain of spastic reactions affecting the entire animal organism. The appreciation of this physiologic fact permits a better understanding of numerous baffling conditions which, for want of better understanding, we are in the habit of dismissing as being of "functional nature." To illustrate this point, I wish to mention here several typical cases:

A forty-five year old U.S. Navy Commander was suffering for years from attacks of epigastric pain ending in vomiting. Repeated

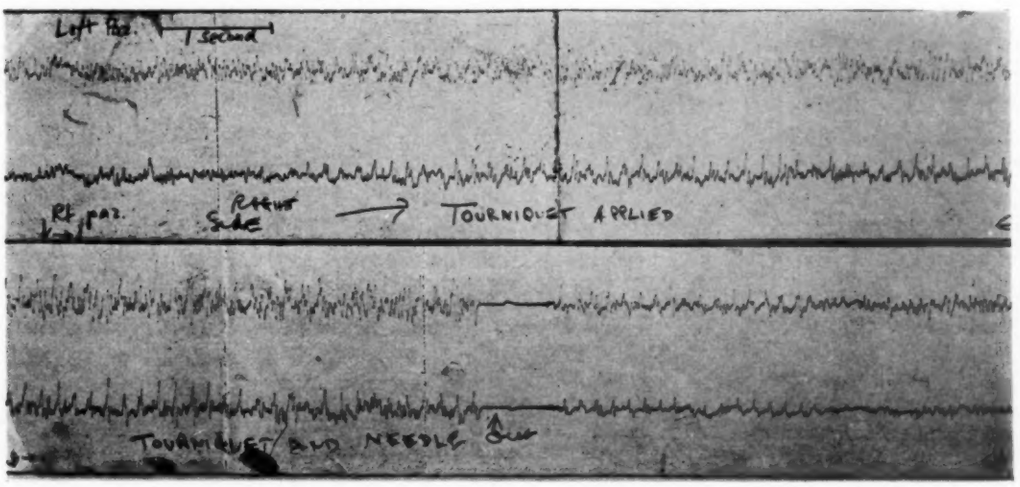

Fig. 2.

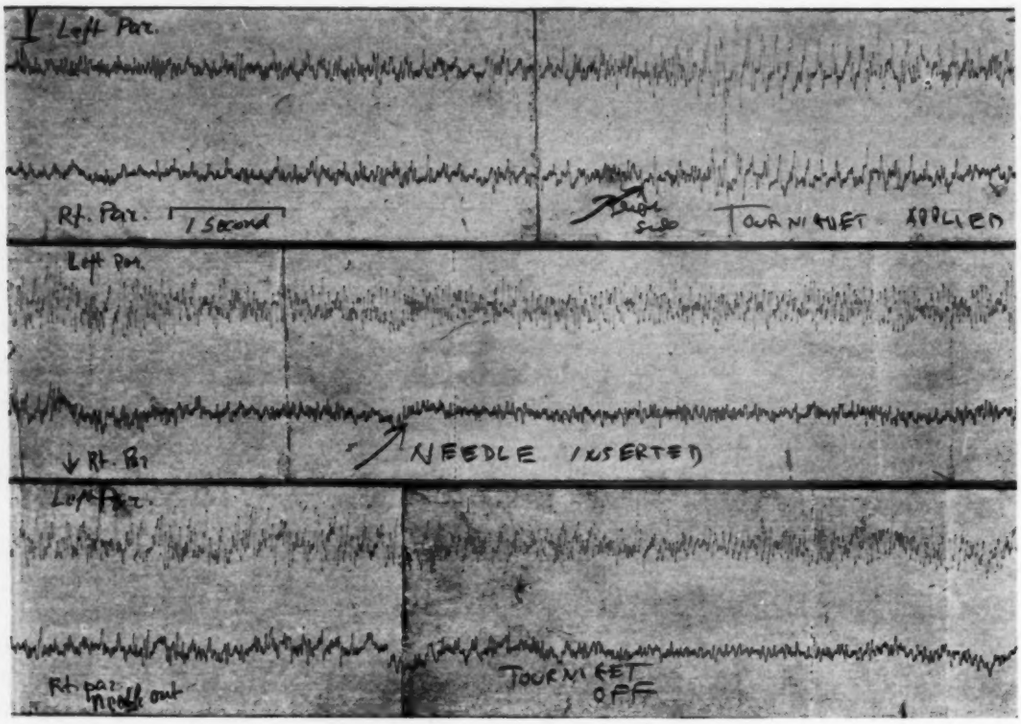

FIG. 3.

examinations revealed a pylorospasm of a "functional nature." Questioning of the patient disclosed that immediately before an attack of epigastric pain he suffered from paresthesias and vascular disturbances in the right hand, especially in the ulnar distribution. A cervical rib was found on x-ray examination and after a division of the anterior scalenus muscle and partial resection of the rib, the man has been free from the paresthesias in the right hand as well as from attacks of pylorospasm.

A forty-eight year old woman suffered an injury to the right index finger. Amputation through the basal phalanx left a painful stump covered with blue, cold, clammy, sweating skin, adherent to the bone. Gradually the pain from this stump commenced initiating attacks of precordial pain with all the characteristic features of angina pectoris.

A woman, forty years old, suffered for years from recurrent phlebitis of the left leg. However, there was no swelling of the left leg or ankle. After an attack of acute myositis of the lower back, the phlebitis in the left leg became exacerbated and the left ankle and leg swelled. This again subsided with the disappearance of the disability in the back. The spasm of the spinal muscles and their blood vessels led to a reflex spasm of the pathologic veins.

Finally, a personal observation. Recently the writer underwent a thoracic surgical operation. On the tenth postoperative day a phlebitis of the right calf manifested itself by localized pain in the calf, especially on standing and by a reflex pain in the right ring finger which was frostbitten years ago. Ordinarily, the pain in the ring finger would appear only in cold weather. When on the following day a ligation of the right femoral vein was carried out, the pain in the finger subsided immediately upon sectioning of the vein. With the involvement of the wall of the inflamed vein in the right calf, the vein ceased to be a vessel and became a diseased plexus of nerve fibers which initiated vasospastic impulses elsewhere by reflex action.

In all these cases the vasomotor mechanism is the main factor in the reflex development of the associated pathologic conditions. A vascular spasm at one point sets off a reflex chain of similar spasms throughout the body. It indeed appears that our present day approach to vascular spastic conditions is a faulty one. We have in the past considered as independent clinical entities such conditions as angina pectoris, migraine, vascular cerebral insult, Meniere's syndrome, idiopathic epilepsy, essential hypertension and pylorospasm. We should look at all these and other spastic

conditions as manifestations of the same pathogenesis, namely, vascular spasm, rather than as unrelated and independent clinical entities.

A number of common clinical observations by the writer supports this view of the intimate reflex interrelationship between vascular spasm in various parts of the body. Massage of the prostate immediately raised the blood pressure from an average of 120/85 before massage to 155/95, with return of the pressure to normal some fifteen minutes after the massage. Bimanual palpation of the uterus raised the blood pressure from an average of 115/80 before examination to 140/90 immediately after palpation. Venous pressure was measured as an index of spasm or narrowing of the vascular bed in cystoscopy. The venous pressure rose about 25 per cent when the cystoscope was passed through the male urethra. The pressure then returned to normal and rose again 20 per cent when the bladder was distended with the irrigating solution. After the catheter entered the ureter a new rise in venous pressure was observed. In other words every spasm about the urethra, the bladder and the ureter caused an immediate rise of venous pressure or narrowing of the vascular bed.

Present day conception of the sympathetic innervation of blood vessels of the limbs is based upon a series of four neurons: (1) Cortico-hypothalamic; (2) hypothalamic-spinal; (3) pre-ganglionic, and (4) post-ganglionic. This conception presupposes a decussation in the pons. My experiments do not support this view. *Not all* the post-ganglionic fibers destined for blood vessels join the peripheral spinal nerves. Many reach the main artery of the limb as direct branches from the sympathetic ganglia. We saw that application of the tourniquet on the right arm reflected first and most upon the right cerebrum and only secondarily on the left cerebrum. A vasoconstrictor impulse ascending from a spastic focus reflexly activates the whole ipsolateral sympathetic nerve supply and soon flows over to the sympathetic system of the contralateral side.

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CAUSALGIA

FRANK H. MAYFIELD, M.D.
Cincinnati, Ohio

THE concentration of peripheral nerve injuries in centers by both the British and American Military Services early in World War II permitted the study of large numbers of patients with painful post-traumatic dystrophies by experienced men. Leriche, whose experiences are summarized in his monograph,[1] as early as World War I had shown that the sympathetic nervous system was intimately involved in these painful states, yet the pain mechanism has remained obscure. During the interval between World War I and World War II, numerous reports[2–5] verified the observations of Leriche, that interruption of the sympathetic chain would relieve the pain in true causalgia and the so-called minor causalgias, such as Sudech's atrophy and painful osteoporosis.

There has been much confusion concerning diagnosis, treatment and etiology of the causalgic states. Certain writers[6,7] have held that true causalgia, as originally described by Weir Mitchell,[8] Sudech's atrophy, painful osteoporosis and the so-called minor causalgias are but different expressions of the same underlying disorder, and indeed painful phantom limb has been included. Other writers[5,9,10] have been equally convinced that true causalgia is a clinical entity unrelated to the less severe states. For a time the writer found himself in this group, but with increasing experience this view has altered somewhat, so that now it is believed probable that the majority of the painful post-traumatic dystrophies, with the exception of painful amputation stump and true hysteria, are expressions of the same underlying disorder. The confusion which has prevailed and the wide differences of opinion which have arisen seem to have developed from the tendency on the part of various authors to pursue features of these syndromes that differ, rather than to seek a common denominator among them.

It shall be my purpose in this paper to present in summary the data from 105 cases of true causalgia seen in the military service and treated by sympathectomy (already reported elsewhere in papers by the author with Devine and with Ulmer[12]). These data appear to permit support of the theory of Granit, Leksell and Skoglund[14] and of Doupe, Cullen and Chance[15] relating to the causative mechanism, namely, that it is a shunt of efferent sympathetic impulses into the sensory somatic fibers at the site of injury to the nerve.

In the 105 cases upon which this paper is based, a penetrating wound of large peripheral nerves was the causative agent in each case. The nerve injury was incomplete in every instance. In an overwhelming majority of cases, the median or sciatic nerve was involved. The onset of pain was instantaneous in approximately 50 per cent. In the remainder the onset was delayed for intervals varying from fourteen hours to three months. None were associated with injury to the major blood vessels, and infection of the wound was rarely encountered. The ages ranged from nineteen to thirty-nine years. The disease was observed in approximately 5 per cent of all patients admitted to the Percy Jones General Hospital with wounds of peripheral nerves.

The outstanding complaint in each case was burning pain. Usually it was most intense in the autonomous zone of the involved nerve. While the pain was continuous, it was exaggerated by emotional and environmental stimuli. It was associated with vasomotor manifestations of two types, one vasodilatation and the other vasoconstriction. Generally the skin of these in vasodilatation was dry, scaly and warmer than the normal extremity, and the hair of this member was often long and coarse. The skin of those in vasoconstriction was usually cold, thin and glistening and sweated profusely. In this group there was usually loss of hair and tapering of the digits. Vasodilatation was a more common phenomenon than vasoconstriction. In a small percentage of the patients, no alteration in blood flow was noted.

Many patients obtained some relief of pain from the application of moisture to the painful part. If the extremity were in vasodilatation, cold water gave relief. If the part were in vasoconstriction, warm water produced comfort. Weir Mitchell[8] had believed that moisture was the factor which produced relief. Our own

observations indicated that the temperature was responsible, for patients in vasoconstriction with malarial fever were relieved during the bouts of elevated temperature, and this was confirmed when artificial fever was induced. On the contrary, patients who were in vasodilatation experienced exacerbation of the pain when the temperature of the painful part was elevated.

Emotional stimuli such as fear, anger, and/or disturbing noises produced exacerbations of pain. The slightest motion or touch of the part was painful. In the more severe cases, the patients' facial expressions reflected severe pain. They usually grasped the painful extremity just proximal to the wrist or ankle to hold it immobile. They would avoid emotional and environmental stimuli by seclusion in a dark room. As a rule they showed no interest in family or friends, even though they had been absent overseas for many months.

Many patients of this group were submitted to psychiatric interview after the pain was relieved by sympathectomy, and no evidence of predisposing constitutional factors was revealed. With rare exceptions, the individuals proved to be entirely stable. The high strung, tense individual appeared to experience more severe exacerbations of pain than the more placid types, however.

Approximately 20 per cent of the patients showed spotty osteoporosis of the small bones of the extremity. The remainder showed no change.

TREATMENT

Block of the appropriate sympathetic chain with procaine would produce dramatic relief. As a rule the relief following procaine injection would persist for one to two hours, or approximately the period that a local infiltration is effective. In a few cases the pain remained greatly reduced for prolonged periods after the injection. In none did it remain completely well, though many patients were given six to eight injections. This is in contrast to the experience of certain writers,[4,13] and indeed the author has observed lasting relief by this procedure in an occasional case of minor causalgia.

Neurolysis was done on many of these patients without relief. Periarterial neurectomy done at the level of injury on eight provided no relief. Periarterial neurectomy of the proximal portion of the vessel was not done. In six patients resection of the injured segment of nerve was done, and complete relief of pain followed. In the remainder, relief was provided by sympathectomy. In nine patients, the initial sympathectomy failed to provide complete relief. In two of these in which the arm was involved, it was shown subsequently that the fourth rib had been inadvertently removed instead of the third and that the sympathectomy was incomplete. In seven cases in which the lower extremity was involved, some pain persisted after removal of the second and third lumbar ganglia. Sweating tests revealed that the sympathectomy was incomplete. In two of these removal of the first lumbar ganglion was sufficient to complete the sympathectomy and relieve the pain. In five, dorsal ganglia 11 and 12 were removed, after which the sympathectomy was complete and relief was provided. No patient was permanently relieved by repeated procaine blocks. Two patients previously discharged from other neurosurgical centers as cured by repeated procaine blocks subsequently developed a recurrence of pain after being transferred to the Convalescent Hospital attached to our unit, and these were treated by sympathectomy with relief.

The chief residual after relief of pain by sympathectomy consisted of stiffness of the small joints of the hand, which was attributable to prolonged disuse. It was frequently difficult to overcome. The other residual depended upon the extent of the nerve injury.

COMMENT

Among the theories relating to the causative mechanism in this disorder are infectious neuritis and fibrosis about the nerve. The fact that infection was rarely observed and the onset of the pain so often occurred at the moment of impact disproves this hypothesis, and the frequent early development of pain also disproves fibrosis about the nerve at the site of injury as a factor. The complete absence of vascular injury in this group eliminates this theory from consideration. Certain writers[1,2,5] have considered ischemia to be a factor. Others have thought that hyperemia induced the pain. However, many patients are observed in vasoconstriction, while others are in vasodilatation, yet the pain is relieved by interruption of the sympathetic chain. This would make it appear that the alterations in blood flow are the result of pain rather than the cause of it.

Psychogenic factors influence the pain remarkably but cannot be considered as the

etiologic agent, for many of the patients upon which this paper is based had withstood emotional experiences far greater than that of the wound without such complaints. Furthermore, when relieved of the pain, all evidence of emotional instability disappeared.

The spotty osteoporosis, considered a cardinal feature of Sudech's atrophy or painful osteoporosis, probably is not a causative factor in the production of pain, for it was noted in less than 20 per cent of the patients of this group, and my own experience would indicate that it is not a consistent finding in the minor causalgias.

In 1944, Granit, Leksell and Skoglund[16] recalled attention to the fact that there is a constant interplay of impulses between the sympathetic and somatic fibers of any mixed nerve. This interplay is greatly increased when a segment of nerve has been injured, probably as the result of fragmentation of myelin at the site of injury, and they advanced the hypothesis that the underlying mechanism in the causalgic states was a shunt of efferent sympathetic impulses into the sensory fibers at the site of injury. Doupe, Cullen and Chance[17] on the basis of clinical experience and laboratory evidence supported this view, and more recently White, Heroy and Goodman[18] have given added support, and the writer finds that his own observations are compatible with this view.

With rare exceptions, causalgia results from nerve wounds that are incomplete. The onset of pain may be instantaneous or may be delayed for several weeks. Excision of the injured segment of nerve always provides relief of pain, and complete sympathectomy of the involved part has provided relief in every instance of the writer's experience. Neither external nor internal neurolysis influences the pain. Periarterial neurectomy when done at the site of injury does not influence the pain. The author has had no experience with periarterial neurectomy done on the proximal portion of the vessel as advocated by Leriche.[1] However, it is not believed that periarterial neurectomy interrupts fibers that are not also included when removal of the appropriate portion of the ganglianated chain is accomplished, as has been suggested by Hermann, Caldwell and Reineke.[3] As has been pointed out by White, Heroy and Goodman,[18] the emotional and environmental factors which exaggerate the pain in patients with causalgia, and which in the past were thought to be evidence that the disease was hysterical, have one common denominator, namely, the increase of the outflow of efferent impulses from the hypothalmus over the sympathetic chain. The factors which provide relief of pain in the causalgic states, such as quiet or sleep, the application of warm water in vasoconstriction or cold water in vasodilation, are factors which reduce the out-flow of sympathetic impulses from the hypothalmus. The majority of the data, therefore, seemed compatible with the hypothesis that the pathologic mechanism of causalgia does indeed consist of a shunt of impulses from the sympathetic nerves into the sensory fibers at the site of injury to a mixed nerve.

It is difficult to explain on this hypothesis, however, the relief which is reported at times by one or more procaine injections of the sympathetic chain and the occasional failure reported by certain writers when sympathectomy was done. It is possible that the failure of sympathectomy to provide relief at times is due to an incomplete sympathectomy as the result of anomalous innervation when the lower extremity is involved, as has been shown in seven cases in this group, or to the inadvertent removal of the wrong rib when dorsal sympathectomy is performed, as has occured in two cases in my own experience.

The spontaneous recovery which is observed in cases of causalgia may be due to the redeposit of myelin about the sensory fibers, thereby arresting the shunt. The relief which is reported for repeated novocaine blocks remains the most difficult phenomenon to account for. My own experience in the management of true causalgia suggests that the relief may be relative. A patient who is suffering intense pain may mistakenly regard himself as completely well for a short time if his pain is greatly reduced. It is also possible that repeated injections may hold the pain in abeyance sufficiently to permit spontaneous healing of the lesion.

It is not my purpose in this paper to discuss the minor causalgias. However, it is considered in order to state that the writer considers the causative mechanism in true causalgia and the so-called minor causalgias similar. It is probable that the differences are ones of degree. In true causalgia, with rare exceptions, the lesion is of a large mixed nerve and is the result of a penetrating wound, whereas in the minor causalgias, mild trauma about the small

joints is a more frequent cause. It is possible that the complaint of intense burning pain in true causalgia, as compared to a throbbing, aching pain in the less severe states, which is the chief difference, may be accounted for by the involvement of large numbers of superficial sensory nerves in one case, as compared to smaller nerves which serve tendons and ligaments in the other.

SUMMARY AND CONCLUSIONS

The data from 105 cases of true causalgia observed in the military service suggests that the painful mechanism of causalgia consists of a shunt of sympathetic impulses into the sensory fibers at the site of injury.

The diagnosis of causalgia can be established by block of the appropriate sympathetic chain with procaine, and it appears that repeated injections occasionally may provide relief. In the great majority of instances, however, appropriate sympathectomy should be carried out. For the arm, the dorsal preganglionic sympathectomy of Smithwick is the procedure of choice. When the lower extremity is involved, removal of ganglia L-2 and L-3 is effective in most instances. If this procedure fails to provide relief, sweating tests should be carried out to determine if the sympathectomy is complete; for in occasional instances, removal of the L-1 ganglion or the dorsal chain as high as D-11 may be necessary. While periarterial neurectomy unquestionably will provide relief in certain cases of minor causalgia or painful osteoporosis, this operation appears to hold no advantage over removal of the appropriate portion of the sympathetic chain, and it is more likely to fail. The risks and morbidity of the two operations are comparable. It is believed that treatment should be carried out early to avoid the crippling stiffness of disuse of the small joints and the psychic trauma of prolonged pain.

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DISCUSSION

John W. Devine, Jr. (Lynchburg, Va.): I have enjoyed this excellent paper of Dr. Mayfield's and wish to congratulate all of the essayists on their presentations this morning of this interesting and confusing subject.

My interest in causalgia started while I was a junior in medical school when a member of my family developed causalgia following an accidental gunshot wound of the median and ulnar nerves. I had the opportunity of studying in detail twelve other cases with Dr. Mayfield. I believe that we should limit our use of the term causalgia to severe painful extremities following gunshot wounds of peripheral nerves, as originally described by Dr. Weir Mitchell. I do not deny that the other conditions are not similar, but if we use this term in speaking of other types of painful syndromes, it confuses the picture even more. There were several conclusions that we came to regarding these patients, which I shall repeat. All of these patients were combat soldiers returning from long tours of

overseas duty. They were interested in only one thing, getting relief from this unbearable pain. They were not interested in leave, pay or even in the opposite sex. All were relieved by novacain injections of the sympathetic ganglion for the duration of the novacain anesthesia only. They all had vasomotor disturbance, which was manifested by vasodilitation or vaso constriction.

Why they occurred in some cases, and not in others, and why some of them cleared up spontaneously has not been explained. Adequate sympathectomy gave these carefully selected patients relief. I cannot agree that the explanation of this has been explained as yet. In this regard, I would like to comment that I have been impressed with the fact that the neighboring lymphatics were greatly enlarged at the time of the sympathectomy. It has occurred to us, but we were unable to prove it, that this might be an inflammatory process we were dealing with. An inflammatory process is one of the few pathologic conditions that occasionally clears up spontaneously. Interrupting and removing the sympathetic ganglion cures this condition and yet patients who have had a sympathectomy and splanchnicectomy for hypertension often have severe excruciating pain from intercostal neuritis, even when the intercostal nerve is cut at the cord. Certainly these patients have had an adequate sympathectomy and many of them have very severe pain which is similar to causalgia.

Regardless of what the etiology of this syndrome is, a great contribution has been made, since sympathectomies relieve the pain in this disease. Even, if we do not know the physiology and pathology of this condition, a great advancement has been made in that we were able to relieve the suffering in these pathetic patients.

Elisha S. Gurdjian (Detroit, Mich.): I just wish to say, Mr. President, that to paraphrase Dr. Coller when he discussed the paper by Dr. Elkin on 400 cases of arteriovenous aneurysms of the trunk and extremities, all of us put together probably will not see 107 cases of true causalgia in twenty years of practice. It is rather interesting that Dr. Elkin, in these traumatic arteriovenous aneurysms, did not use sympathectomy or sympathetic blocks before operation.

I would like to ask two or three questions. Was the spotty osteoporosis seen in those patients who had vasodilatation with peripheral resistance, or was it equally divided among those with vasoconstriction as well as vasodilatation?

Second, if sympathetic block and T.E.A. block does not help the patient, should one go ahead with sympathectomy in some of these cases?

Third, how about these so-called minor causalgias, patients whose hands look perfectly normal even though a portion of the phalanx has been removed, who complain bitterly of pain and who usually are compensation cases? And how about this group of cases that we all see, who will go from doctor to doctor, and who are not aided by T.E.A. block or block of the sympathetic ganglia? What is the management of these cases? Does he have any experience in the matter of sympathectomy in this group?

Frank H. Mayfield (closing): I wish to thank Dr. Devine and Dr. Gurdjian for their discussion.

Dr. Devine has raised the question of inflammation as a possible etiologic factor in causalgia. I believed that I made my view clear in the paper. The fact that the great majority of patients with causalgia develop symptoms immediately at the moment of impact eliminates inflammation as an etiologic agent.

Dr. Devine has also raised the point that spontaneous recovery occurs only in inflammatory disease. I would like to draw his attention to the matter of traumatic injury of the myelin sheath. Trauma will fragment myelin; however, it is capable of spontaneous replacement.

In regard to his remarks concerning the postoperative pain in patients who have had sympathectomy for hypertension, I must state that I have seen no patient in whom the postoperative symptoms resembled causalgia. It is true that many have postoperative paresthesias and also aching pain, but I do not believe that they can be classed with causalgia.

Dr. Gurdjian has asked a very pertinent question concerning the relation of osteoporosis as demonstrated with x-ray to the status of the blood flow in the affected extremity. It was our impression that those patients who showed vasodilatation in the involved extremity were more apt to show osteoporosis than those with vasoconstriction. Unfortunately, we do not have documentary data in regard to this that are reliable.

Dr. Gurdjian has also asked what our plan of management is in those patients with painful post-traumatic dystrophies who are not relieved by novocain block of the appropriate sympathetic chain. I presume that this question was prompted by material presented in other papers in the symposium which, unfortunately, I failed to hear due to the late train. I am convinced that diagnostic novocain block is essential in causalgia and in the so-called minor causalgias, and that one is not justified in performing a sympathectomy on an extremity for the relief of pain unless a preliminary diagnostic block has been done and has been effective. Furthermore, we regard with considerable skepticism patients who obtain prolonged periods of relief after block of the sympathetic chain with procaine. For the most part we have depended upon the psychiatrists for help in that group of patients who do not obtain relief with procaine block, and we definitely believe that the painful phantom limb falls into an entirely separate category.

RÔLE OF THE SYMPATHETIC NERVOUS SYSTEM IN TRAUMATIC SURGERY

AS APPLIED TO FRACTURES, CAUSALGIAS AND AMPUTATION STUMPS

H. GURTH PRETTY, M.D.

Diplomate of the American Board of Surgery; Lecturer in Surgery, McGill University; Associate Surgeon Montreal General Hospital

Montreal, Canada

THE present conception of opinion is that the sympathetic nervous system functions through a reflex arc. The reflex arc appears to carry sensory pain fibers and motor fibers to the arterioles and possibly lymphatics. Sympathin and adrenalin possibly act as boosters to the sensitivity of the sympathetic system with actual stimulation arising from the vessels in the neighborhood of trauma or as a result of pathologic changes in vessel walls such as atheroma or thrombosis.

Interruption of the reflex arc inhibits sensations of pain; whereas stimulation enhances pain, constricts the arterioles and produces a blanched, cold, moist, edematus limb with poor capillary response. If, however, under conditions of stimulation the sympathetic is interrupted, the response is a painless, warm dry limb with excellent capillary response, with return to better than normal color and gradually subsiding edema up to seventy-two hours.

Interruption of Sympathetic. 1. Tetraethylammonium chloride administered intravenously 3 to 5 cc., gauged by fall in blood pressure, in a 20 per cent solution, begins to work in about fifteen seconds with a maximum effect in fifteen minutes. This lasts about thirty minutes but gives relief of pain for about one to two hours.

2. Lumbar sympathetic block or dorsal sympathetic block, using three to four needles to administer (1) 2 per cent novocain, (2) 1 per cent procaine, (3) proctocaine or xylocaine and (4) absolute alcohol. The latter is more lasting and satisfactory but has the danger of producing an alcohol neuritis if carelessly administered.

3. *Ramisectomy and Ganglionectomy.* (1) Ramisectomy is advised for upper limb lesions; (2) ganglionectomy is advised for lower limb lesions, taking care not to remove the fourth lumbar ganglion. Ramisectomy and ganglionectomy are recommended procedures whenever possible, irrespective of response to sympathetic block procedures or tetraethylammonium.

The thermacouple and oscillometer are not necessary to gauge response. The well trained surgeon's hand can detect (a 2–3) degree change in rise of temperature, plus dryness of extremity and response of capillaries to compression of thumb on the plantar surface of the great toe.

Response to Trauma. The physiologic and pathologic pre-existing status of an individual plays a very important part in the presence of trauma; eg., (1) the healthy young agile individual versus the aged arteriosclerotic; (2) the individual who is a clotter versus the hemophilic; (3) the individual with sympathetic imbalance—anxiety status (moist, cold with poor capillary response); (4) those with, (a) Raynaud's syndrome, (b) Buerger's disease, (c) vasospasm, (d) acrocyanosis (e) livido Reticularis, (f) erythromelalgia, (g) intermittent claudication syndrome and (h) arteriosclerotic diabetis.

Unfortunately in traumatic cases, in general, we are confronted by a new patient, who makes his first appearance shrouded by pain, mental anguish and shock. Nevertheless, as the patient is investigated we must not forget the possibility of any of the pre-existing vasomotor disturbances, so as not to be taken by surprise when the injured extremity becomes cold, blanched, edematus or shows impending gangrene. All are aware that some patients develop acute bone atrophy, others have more than usual pain, while some develop a very extreme edema and fortunately only a few cases of impending gangrene. The above responses do not bear any relation to the severity of the lesion; in fact, they are more frequently associated with less severe trauma. I believe

that an explanation of these phenomena can be explained on the basis of pre-existing vasomotor changes, with, in some cases, a blood dyscrasia, allowing intravascular clotting in vessels of diminished caliber. The latter offers an explanation for the so-called traumatic phlebitis which we all admit does exist.

Refrigeration versus Interruption of Sympathetic. Refrigeration will inhibit pain, reduce edema and produce dilatation of the capillaries. When, however, the refrigerated limb is allowed to approach room temperature, the response is acute and excruciating pain, and massive edema with blebs and fever.

In short, refrigeration should be used only in cases in which amputation is inevitable. Interruption of the sympathetic inhibits pain, prevents or reduces the edema and produces vasodilatation, temperature rise and dryness. Another phenomenon develops, situated at the junction of ice and air, or rather just above the area of refrigeration which resembles venous thrombosis. In patients refrigerated for several days the skin in this area undergoes necrosis or if incised for amputation purposes undergoes necrosis. We have prepared sections of these areas and found to our surprise that we were not dealing with venous thrombosis but dilated vessels and venous stasis. Based on these findings in cases requiring prolonged refrigeration, for constitutional reason we have modified our technic? Refrigeration is carried only to the mid-calf when amputation is considered above the knee and the actual amputation is carried out under cyclopropane anesthesia.

Fractures and Crush Injuries. Interruption of the sympathetic nerves as soon as possible after injury releases pain, inhibits or reduces edema, overcomes blanching of extremity and allows a moderate amount of active motion. The response to tetraethylammonium is remarkable, but not so lasting or dramatic as alcohol block or sympathectomy, but nevertheless is well worth while. Sympathetic interruption enables reduction of a fracture with marked edema in about seventy-two hours, instead of a delay of seven to ten days with elevation of the extremity at room temperature.

In crushing injuries to the hand and foot, we are all aware of the degree of temporary disability and the vast lapse of time in rehabilitation. I urge early and complete sympathetic interruption in these cases. In my experience the results have been most remarkable. These patients derive a sense of well-being with only one-third of the convalescence.

Case 1. Miss E. R., age forty-nine suffered a crushed right foot caused by a bus tire. Etamon, 3 cc., reduced her blood pressure from 190/80 to 87/60; it stopped the pain for one hour and was repeated daily for three days. The skin became wrinkled and the edema subsided. The patient walked in elastoplast in fourteen days and ten weeks postoperatively the blebs and ulcer base healed. In eight weeks no edema was present and there was only slight limitation of dorsi flexion (no bone atrophy).

Traumatic Thrombophlebitis and Phlebothrombosis. Interruption of the sympathetic in conjunction with anticoagulants should be used prior to thrombotomy and venous resection and the latter resorted to only in selected cases.

Acute Bone Atrophy. Periodically, and fortunately not too often, we are confronted with a hand or foot, glossy and edematus, slightly cyanotic, over which the patient has very little active movement. The x-ray reveals acute bone atrophy. Passive manipulation enhances the condition whereas interruption of the sympathetic produces astounding results in twenty-four hours. I will not discuss periarterial sympathectomy versus ramisectomy or ganglionectomy as space does not permit. The maltreated case with prolonged aggravation becomes psychoneurotic. This type should not be submitted to interruption of the sympathetic and may require amputation.

Causalgias. Causalgias, in my opinion, follow minor injuries to extremities or trauma to major nerves in individuals with a preexisting sympathetic imbalance. Saw cuts or frost bites to digits frequently produce a typical causalgic pain. I can recall three sawyers and one teamster, all of whom develloped a severe causalgia, necessitating loss of time from work. They all responded to ramisectomy, resumed work in three weeks and remained free of pain.

Amputation Stumps. The phantom limb or the causalgic stump is rarely seen if amputation is carried out with care. When sympathectomy is indicated it should be carried out prior to amputation. Contraindications should be mentioned in the case of an associated cellulitis of the limb to be amputated, other-

wise the metabolism will be raised and amputation will of necessity have to be taken higher.

We have not experienced any cases of phantom limb in the use of refrigeration anesthesia or refrigeration preparation prior to amputation.

Technic of Operation. For an upper limb we use ramisectomy rather than stellectomy; for a lower limb lumbar ganglionectomy, through the back (1–2–3) is employed.

CONCLUSIONS

1. Interruption of the sympathetic will play a great rôle in traumatic surgery, more especially those with a pre-existing sympathetic imbalance.

2. The crush injury has been discussed.

3. Sudek's atrophy can be relieved of pain and the bones re-calcified.

4. Traumatic phlebitis has been referred to.

5. Refrigeration methods versus sympathetic interruption are discussed.

6. Fractures with massive edema may be reduced and placed in plaster seventy-two hours after sympathetic interruption instead of ten to fourteen days.

7. The remarkable results upon causalgias have been referred to.

8. Sympathectomy in amputation cases brings forth a debate.

9. Technic of operation were referred to with special reference to my posterior approach to the lumbar ganglia utilizing the lower part of the sympathectomy and splanchnicectomy incision.

SURGICAL TREATMENT OF CAUSALGIA

CASE REPORT*

HERBERT M. ELDER, M.D.
Montreal, Canada

THE patient, J. C., a Canadian infantryman, was wounded by a shell fragment in March, 1945.

He sustained a jagged wound of the back of the left thigh, which exposed but did not sever the sciatic nerve. The wound was débrided in a forward Surgical Center within six hours of wounding. The note made at the time states that there had been moderately severe bruising of the sciatic nerve but that there was no paralysis.

Forty-eight hours later the patient began to experience an acute burning pain in his left heel, which was not relieved to any appreciable extent by opiates.

Secondary wound closure was carried out at the base, and he was later evacuated to U.K. to the Neurological Center because of the causalgia. He had become very emotionally disturbed and was very difficult to treat, since he detested any physical contact whatever, stating that it aggravated the pain in his heel. He had also made the discovery for himself, that by picking up a glass of ice water and keeping his hands chilled minimized the pain in the heel.

A number of lumbar blocks were done, which gave temporary relief, and he was sent back to Canada. He unfortunately was "lost" for a time by those who had treated him in England, and no further real treatment was given. He had by this time become so hysterical that he was sent to a psycopathic ward for a while.

After being "found" again, he was further treated by lumbar blocks, and when his condition had been improved selective blocks were used to determine which ganglia it would be necessary to remove. It was found that he could be completely freed of his pain only when L1, 2, 3 and 4 were blocked.

The most striking thing when first seen by the writer was the dramatic change wrought by this procedure. The patient, who beforehand was a cringing, half sobbing, incoherent travesty of a man, continually wringing cold water over his hands from a piece of cloth kept moist from a bottle (a procedure which had produced marked maceration of both palms) became a smiling intelligent human being, who would give a coherent history, move about, shake hands and even permit his hair to be cut.

On the basis of these tests it was decided to do a thoracolumbar ganglionectomy removing L1, 2, 3 and 4, and to play safe, on the basis of some recently published reports, T11 and 12 as well. This was done in March, 1947, two years after his wounding. The operation was carried out as a one-stage procedure, with complete and permanent relief of his pain to date.

After his recovery from this operation, his sciatic nerve, which had been caught in the scar of his wound, was dissected out and freed. This was done for two reasons; (1) there was some weakness of dorsi-flexion of his foot, and (2) to attempt to prevent recurrence of similar symptoms, or the setting up of some other syndrome, by irritation of the sciatic nerve. He is at present symptom-free and his foot weakness is decreasing.

DISCUSSION OF PAPERS BY DR. KOLODNY, DR. PRETTY AND DR. ELDER

FRANKLIN JELSMA (Louisville, Ky.): In reference to the paper, "The Sympathic Reflex Arc and Its Clinical Significance," by Dr. Kolodny, I wish to commend Dr. Kolodny upon his efforts to understand better the principles of causalgia. We are definitely in need of this information. When the literature has been thoroughly investigated and the new texts that are available have been studied, one will find that there is very little detail, very little definite information and very little in the way of facts concerning the mechanism that is related to the production of causalgia or the pain that we know occurs in this syndrome.

As a result, we have many explanations, most of which are of a completely presumptive character. There has not been so far an anatomic explanation for causalgia. It still remains a matter of theory.

In the few minutes I have available, I would like to review briefly for you what some of the neuroanatomists think about this problem.

Rasmussen thinks that there are definite sensory fibers supplying all blood vessels.

Clark, in his newly revised edition of Ransom, speaks of vasomotor fibers as sympathetic fibers. He speaks also of the visceral afferent fibers supplying the blood vessels. In this way, we have a definite reflex arc.

Now, just what happens in the production of pain with this sort of a mechanism is not known,

* A film was shown of this patient during the delivery of the paper.

but it is thought that there is an injured sensory fiber in the periphery. This fiber, or injured area, sends up a barrage of sensory impulses to the brain. This barrage of sensory impulses may distort the ordinary sensory pattern and cause a short-circuiting of the impulses to other portions that ordinarily would not receive the impulse. The somatic motor fibers are stimulated. The autonomic efferent fibers or the ordinary sympathetic fibers are stimulated, and then the continued barrage of sensory impulses to the brain and the continued barrage of motor impulses from the hypothalmus causes a peripheral change. After a while this will produce a definite reflex that is independent of the original reflex or independent of the original source of injury.

There are some who believe, and I am inclined to agree with them, that the central mechanism plays a very important part in causalgia, either because of emotional impulses, because of the individual's natural tendency toward emotion (and some are more emotional than others), or because of a continued barrage of sensory impulses. The person becomes nervous and emotional and there is a group of impulses sent from the hypothalmus to the periphery, the injured nerve, and here it may be short-circuited again to a sensory nerve and carried back to the brain itself.

I would like to mention one thing in the use of sympathectomies. I think it would be a good idea to save the first lumbar ganglion, if at all possible, and also, in the use of tetraethylammonium chloride, intramuscular injection is probably better than intravenous injection for chronic pain such as causalgia.

Elisha S. Gurdjian (Detroit, Mich.): In discussing Dr. Kolodny's paper, I, too, am impressed by the fact that it is through efforts of this type that some of the hitherto unexplained mechanisms will be answered with consequent better management of difficult cases.

I was particularly interested in the electroencephalographic records that Dr. Kolodny showed. The changes that he describes were also obtained in seven or eight of our patients in Detroit. Some of the changes occurred on the opposite side from the body part stimulated. A few of the patients also had changes in the electroencephalogram on both sides. Most of the records show inhibition of the repose rhythm, as he stated.

I think that Buerger and many other electroencephalographers since his time have attributed this sort of phenomenon to the volley of electric impulses from the extremity or other parts of the body to the brain, with consequent inhibition of the ordinary rhythm of the brain or the repose rhythm of the brain, so that there is an inhibition for two to five seconds following such an impulse from the periphery. Opening of the eyes and closing of the eyes, turning on a light and turning off a light and various other things can cause this phenomenon.

However, the explanation that Dr. Kolodny gave, of a possible vasomotor mechanism associated with vasoconstriction in the brain, is interesting and certainly should be looked into very carefully.

However, the vasomotor tone of the central nervous system is not the same as the vasomotor tone of the peripheral circulation. For instance, certain drugs such as carbon dioxide will cause vasoconstriction in the periphery and vasodilatation in the central nervous system. Other drugs will do the same thing. It is a good thing that the vasomotor tone of the brain is difficult to disturb as easily as that of the peripheral system because if the vasomotor tone of the brain were as easily disturbed as the vasomotor supply of one's face (such as redness or pallor), you and I would be fainting many times a day. With this factor of protection, the organism carries on satisfactorily.

All of this may be taken as evidence possibly that the changes that Dr. Kolodny has obtained are due to peripheral stimulation with electrical vollies inhibiting or stimulating the brain wave rhythm rather than due to variations in the tone of the vasculature of the brain in connection with changes in the tone of the vasculature of the periphery. I think that his paper is very stimulating and very interesting.

Ronald W. Adams (Boston, Mass.): These papers have been so well and ably presented to you that your discusser finds it difficult either to add or challenge the statements of the authors.

I confess to a certain amount of bewilderment though on the facts of life as they concern the blood supply in the extremities affected by reflex dystrophy. Dr. Kolodny and Dr. Pretty have ably told you how vasospasm, arteriolar spasm, is the big factor, and yet, in the literature we find the reports of De Takats and Miller, who have studied the problem extensively and who tell us that in the well established reflex dystrophies, there is an increased blood flow to the affected part, as much as 30 per cent.

Quoting from an article that they wrote,[1] "This remarkable increase, persisting over many months and years, is the most characteristic feature of the syndrome. This is true even in those limbs which appear cold to the touch and with shiny, atrophic skin."

The same writers, however, say their patients had a further increase in blood flow following paravertebral block. In the true causalgias, I think I am right in saying that Mayfield and Devine published blood flow studies in their patients, and this was not necessarily true in their group. Some of them had an increased blood flow, others showed a decrease in the blood flow. They also reported cases in which the pain disappeared

[1] *Arch. Surg.*, 46: 469–479, 1943.

with the presence of a hyperpyrexia, such as during the high temperature phase of a malaria attack. Perhaps Dr. Kolodny can tell us the mechanism there involved.

Our experience bears out that of Dr. Pretty, that paravertebral procaine block in the presence of an edema following fractures permits us to perform definitive treatment earlier, and it goes without saying that we prefer to reduce our fractures as an emergency procedure before edema is established.

Our experience with the sympatholytic drugs has not been too extensive. We have not used them for acute vasospasm and arterial spasm. We have used them in the reflex dystrophies but are not quite as favorably impressed as the Ann Arbor group of Barry Campbell, Lyons and others, who have used tetraethylammonium in the reflex dystrophies. Perhaps they have been able to teach their surgeons and residents to recognize the symptoms and signs at an earlier date than we have been able to, or perhaps they have been more persistent in their therapeutic program. We shall continue to use it in selected cases.

Procaine injection, when the symptoms have been well localized to a trigger point, has worked well in our experience, while paravertebral procaine blocks, singly or in repeated doses, have controlled a large number of our patients who present a well established reflex dystrophy. An occasional patient has been found to require ganglionectomy. Our attitude toward it is perhaps rather aptly expressed in a remark of John Homans, who, in discussing this subject, wrote, "Sympathetic ganglionectomy of the White and Smithwick type is a last resort. Those very familiar with it have little patience with less radical procedures. There is a satisfaction in curing the patients with the least possible expenditure of energy, which, I beg to say, is not laziness but artistry."

W. E. Mishler (Cleveland, Ohio): These were very excellent papers. I have nothing to add to the discussion except one practical point, namely, the recognition of causalgia is rather simple and is universally done, but is done late.

I think the plea should be made that inasmuch as trauma is always accompanied by sympathetic reflex mechanism, the measures for the prevention of late results and the early institution of treatment are a "must" in the handling of traumatic cases.

Joseph E. J. King (New York, N.Y.): I want to thank Doctors Kolodny, Pretty and Elder for their splendid presentations. Just think what a fine era we older fellows have lived in and what has been done, especially by the surgeons, for the relief of pain in our time. In the first place, I think that the prime duty of the physician in earlier times was to relieve pain. Dr. Weir Mitchell knew just as much about causalgia at the end of the Civil War as anyone does today, except how to relieve pain permanently.

In passing, one must mention the names of Dr. Charles Frazier and Dr. William Spiller, who instructed us on how to relieve the terrible pain of major trigeminal neuralgia, which has nothing to do with the subject this morning. In recent years a number of good men, such as you have seen and heard this morning, have solved the problem of the terrible pain of causalgia, and the procedure has become commonplace and is universally accepted.

I well remember an old man at Bellevue Hospital in 1923 who had had a large, adherent lipoma arborescens removed from the inner side of his arm by Dr. Tom Russell of Post-Graduate Hospital, New York. Later the patient came to Bellevue Hospital with a terrible causalgia. The median, ulnar and musculo cutaneous nerves were embedded in scar tissue. We did not know what to do except what we knew at that time. We did a neurolysis and that helped him a little. The pain recurred. The man could not sleep and was in terrible pain. Dr. Hartwell made me cut his ulnar nerve and free his median again. That did no good. Dr. Hartwell amputated his arm just below the shoulder, and that did not help. My associate, Dr. Klenke, made an incision over the vertebral column to cut the roots of the nerve. That helped him a little, but the only thing that gave him real relief was when he got pneumonia and died. We knew nothing about sympathectomy in those days.

Now, that operation could be done so easily by any of these men who have talked to us this morning. I want to ask any of the men who read these papers what their experience has been with erythromelalgia, and, second, has anyone been forced to perform cordotomy where sympathectomy has failed?

W. K. Livingston (Portland, Ore.): There are two things that pleased me very much this morning. One was the expression of clinical interest, by an organization of this type, in the influence of the sympathetics on surgical problems. The second was evidence of an experimental approach, such as brought out by Dr. Kolodny's paper. I was also in favor of Dr. Gurdjian's caution in the interpretation of these experimental findings. But we see in some clinics, I think, an excellent utilization of the experimental possibilities in sympathectomy. Bronson Ray is doing some beautiful work in New York with his sympathectomized cases in studying the sensitivity of the alimentary and genitourinary tracts.

There are two points that I would like to mention here that supplement this experimental approach: First, the concept of a vicious circle, if you will, or a cycle of activities set up within integrated neuron systems that becomes self-

sustaining. It has been beautifully exemplified in the work that is being done in experimental Jacksonian epilpesy. There is one other experimental finding from the physiologic laboratory that has a bearing, perhaps, on this remarkable phenomenon we saw in the film, of sensitivity of the skin, expressing itself with added pain in the causalgic area. That was an experiment of Taylor and Porter in Texas, a simple example of "facilitation" which they believed had some bearing on the excessive skin sensitization in causalgia.

They were trying to show how relatively innocuous stimulation can add centrally to reflex activity. Their setup was this: A spinal cat, in which they were stimulating (with each artificial respiration) the posterior tibial nerve and were recording contractions of the anterior tibial muscle. Therefore, they were producing in this spinal cat a reflex. They reduced their electrical stimulus to the minimal amount which would produce a bare contraction of this anterior tibial muscle with each stimulation.

Their record would show on a recording kymograph these minimal contractions of the anterior tibial muscle produced reflexly. With this setup, they dropped cold water repeatedly on the cat's foot. Immediately the reflex contraction of the anterior tibia became greatly exaggerated.

The question now arises, does the dropping of the water on the foot in itself, without the electrical reflex, produce this contraction? When they discontinue the electrical stimuli, there is no contraction of the anterior muscle at all. They now stop the dropping of the water and the muscle returns to its minimal contraction. Exactly this same experiment can be done with a drop of nitric acid on the cat's knee. It can be done by stroking the fur with an applicator. It can be done even by blowing strongly on the hair with a pipette. In other words, they were showing a reflex taking place through the central nervous system in a spinal cat and that when this reflex is at a minimal level, innocuous stimuli such as stroking the fur or blowing air on it or spreading the toes or dropping cold or hot water will tremendously exaggerate this simple reflex response through the agencies within the spinal cord.

Harold C. Voris (Chicago, Ill.): I, too, have greatly enjoyed these very interesting and profitable papers. I have one question that I would like to ask Dr. Elder, and that is, if he has any explanation for the necessity of blocking or removing the fourth lumbar ganglion in his case?

I realize that in cases of this type, we are perhaps getting our effect as much or more by removing visceral afferent fibers as by our sympathetic denervation. Certainly, as I understand it from what we know of anatomy at the present time, there are no efferent sympathetic rami below the second lumbar roots and, therefore, at least from the theoretical standpoint, should it be necessary to remove the fourth lumbar ganglion in order to accomplish sympathetic denervation of the foot? I would like to know if he has any explanation for the necessity of blocking the fourth lumbar ganglion in order to obtain complete relief in this case.

Anatole Kolodny (closing): As to the question asked by Dr. Adams, how Dr. Pretty and I explain the discrepancy between the large volume of blood existing in such an extremity and still have the spasm, I will leave this to Dr. Pretty to answer. I just want to limit myself to two or three points raised by Dr. Gurdjian.

Dr. Gurdjian says that he thinks Dr. Buerger first pointed out that you find an inhibition in the electro-encephalogram, an inhibition after any irritation during the electro-encephalography. You see the patient opening his eyes, or you are talking to the patient or asking him questions. We always find that. But we always find it on both sides of the brain at the same time. I had correspondence with the doctor who I think is probably the most outstanding man today in electro-encephalography, Dr. Gibbs, about that question and he is of the same opinion, that any irritation of the patient at the time electro-encephalography is carried on is not always manifested by inhibition, but sometimes by acceleration of the waves, and it is equal on both sides, while the curves I showed here speak for themselves.

Of course, we doctors are individualists and we like to interpret findings as we think. It is up to the person.

I do not want to enter into any anatomic debate. In my paper, which I did not read in its entirety here, there is a question about anatomy, too. But there is one more important point I want to make, and I want to make it as a patient to doctors. I never learned so much to respect a patient's complaints as I learned during the last five weeks, when I was a patient in a hospital. I used to say that patients were hysterical, like Dr. Elder has said when he saw that boy, namely, that he was in an acute hysterical stage. I used to say it, too. I will give you an example:

I was operated upon on the left side of the chest and have an extensive thoracic scar. At the time I was in the hospital, whenever the nurse used to wash the left side of my face, I had terrific pain in the scar. She would just touch the left side of my face and I would have a pain in the scar. The same thing was true of the left arm. Now, the only rational explanation that I have is that my scar at that time irritated many blood vessels and the slightest irritation on that side, causing contraction of the capillaries and the arterioles, immediately reflected itself in exaggeration of the spasm on the

left side; and I am not a hysterical man. In thirty years of practice, I have never been sick a single day.

H. Gurth Pretty (closing): Dr. Kolodny mentioned that he is not a hysterical individual, but he almost had me in hysterics when he said that I could answer a question that he could not.

Now, one question was brought up, that of increasing the blood volume in a limb after interruption of the sympathetic. I think, because you get an increase in temperature, that does not necessarily mean that you have an increase in blood volume. If you liken the thing to a radiator, if you increase the circulation of hot water through a radiator by means of a circulating pump, that radiator will emanate a great deal of heat. If, on the other hand, you slow up the circulation of the water through the radiator, you emanate less heat; so I do not think it is a question of increasing blood volume but it is a question of increasing blood interchange.

Then comes the question of removal of the first lumbar ganglion and also the question of removal of the fourth lumbar ganglion. That brings in many debates. I do not know how we are going to settle it. Certainly, if you do not remove the first lumbar ganglion, you do not get satisfactory results in any type of sympathetic operation. The disadvantages of removing the first, as we all know, are that it is supposed to interfere with the ejaculator mechanism. That does not seem to apply in every case, in my experience. I have many in whom it made no difference whatsoever, whereas in others, it has; so that is still a debatable question.

As to the question of removing the fourth, I will grant you that by blocking the fourth with the others, you get a good response. You will get a good response up to two and three years after the fourth, but where the fourth has been removed, there is a tendency in these patients to revert after three or four years; in other words, the results are not as good or as lasting as those cases of removing, 1, 2, 3 and not the fourth.

Regarding the question of using tetraethylammonium chloride intravenously versus intramuscularly, there is no doubt that your effect is more lasting intramuscularly, but my point is that by using the tetraethylammonium, you are foolish to attempt to use it as a prolonged method of treatment. The only answer is, if your case requires sympathetic interruption for a long time, by all means be radical about it and do not waste time playing around with tetraethylammonium.

The other question of reducing the edema in fractures, I quite agree that if we get our fractures early and treat them immediately, we do not get edema. That is the ideal situation. But how often do we get our fractures in the big general hospital immediately? Some of them are referred from country districts, from different areas. The edema is well developed. Therefore, we have to use some ways and means of getting that edema down quickly, and your sympathetic interruption will certainly facilitate it.

The question of cordotomy is an old debatable point. I think that is a hanger-on of the neurosurgeons, and they are inclined to swing back to cordotomy. They are inclined to steal the sympathectomies from the other people. I do not believe that by doing a cordotomy after a sympathectomy, you are going to improve the condition. I think, if your condition has gone to such an extent that sympathectomy or interruption will not do it, you had better leave cordotomy alone.

UNUNITED FRACTURE OF THE NECK OF THE FEMUR*

CAUSES OF FAILURE OF INTERNAL FIXATION AND TREATMENT

IRWIN E. SIRIS, M.D. AND JOHN H. MULHOLLAND, M.D,
New York, New York

THE objects of this paper are (1) to cite the pitfalls in the management of fractures of the neck of the femur which contributed to non-union, (2) to stress *prevention of the pitfalls* in order to reduce the incidence of non-union, (3) to urge the use of visual osteotomy when in attempting internal fixation some of the pitfalls seem inevitable and (4) to report our experience with twenty-six ununited fractures of the neck of the femur.

Since Kellogg Speed[1] delivered his oration on the "Unsolved Fracture" in 1935, the transfixion of recent fractures of the neck of the femur has been widely employed. However, the problem is still very formidable. While the immediate objectives may have been obtained, there is no assurance that the transfixion of the fracture will result in osseous union with a functioning and painless hip. Too many factors, known and unknown, play a rôle in interrupting union and in producing degenerative arthritis or aseptic necrosis. (Table 1.)

Sixteen ununited fractures of the neck of the femur are known to have occurred among the 146 which had been pinned on our service during the six years prior to January, 1947. Ten ununited fractures were admitted with no previous treatment, either because of the patient's reluctance to submit or to the physician's failure to recommend operation.

Excerpts from two reports evaluating the intermediate and ultimate results show the need for studying these unsolved clinical problems which remain a challenge to the surgeon: (1) The Fracture Committee of the American Academy of Orthopaedic Surgeons in 1941[2] reported that (1) non-union occurred in forty-one or 23.7 per cent of 173 cases which met the committee requirements for classification as good reduction, viz., anatomic replacement of the fragments or a slight valgus position; (2) arthritic changes were observed in the head following bony union in forty-three or 27.3 per cent of 157 cases following fixation with Smith-Petersen nail or multiple wires. (2) Boyd and George,[3] in their report of the complications and results of internal fixation of 300 acute central fractures of the neck of the femur, found that nineteen or 13.5 per cent of 122 hips failed to unite, nine of these following satisfactory reductions and nailings. They added that aseptic necrosis and arthritic changes in the hip each occurred in 33.6 per cent and that all patients with aseptic necrosis did not have arthritic changes. From their findings they indicated that a good end result could be prognosticated in 43.6 per cent.

TABLE 1
COMPLICATIONS OF 146 INTRACAPSULAR FRACTURES

	No.
1. Ununited fractures	16
2. Degenerative arthritis	4
3. Aseptic necrosis	2
4. Reinsertion of inaccurately inserted nail	18
5. Broken calibrated indented guide wires	4
6. Foreshortening of neck and extrusion of nail	8
7. Absorption of neck and straddling neck and shaft by Smith-Petersen nail	5
8. Infection (6) absorption of head	1
9. Thrombophlebitis and pulmonary infarction (2 recovered)	4
10. Pneumonia	12
11. Died	14

Compere and Wallace's[4] experiments on dogs indicate that the fate of the head of the femur following transcervical fracture is favorably influenced by immediate accurate reduction and internal fixation. If Phemister's[5] theory that the fate of the head following fracture is determined on a basis of injury to the blood supply to the head at the time of fracture, it is logical to reduce the "time lag" between fracture and reduction-fixation. Further damage to the capsular vascular tree by rotation, displacement and shearing stress will be eliminated by early transfixion.

PITFALLS IN THE MANAGEMENT OF RECENT FRACTURES

Our experience has led us to believe that, in some instances, failure to obtain osseous union

* From Department of Surgery, New York University College of Medicine and Third (New York University) Surgical Division, Bellevue Hospital, New York City.

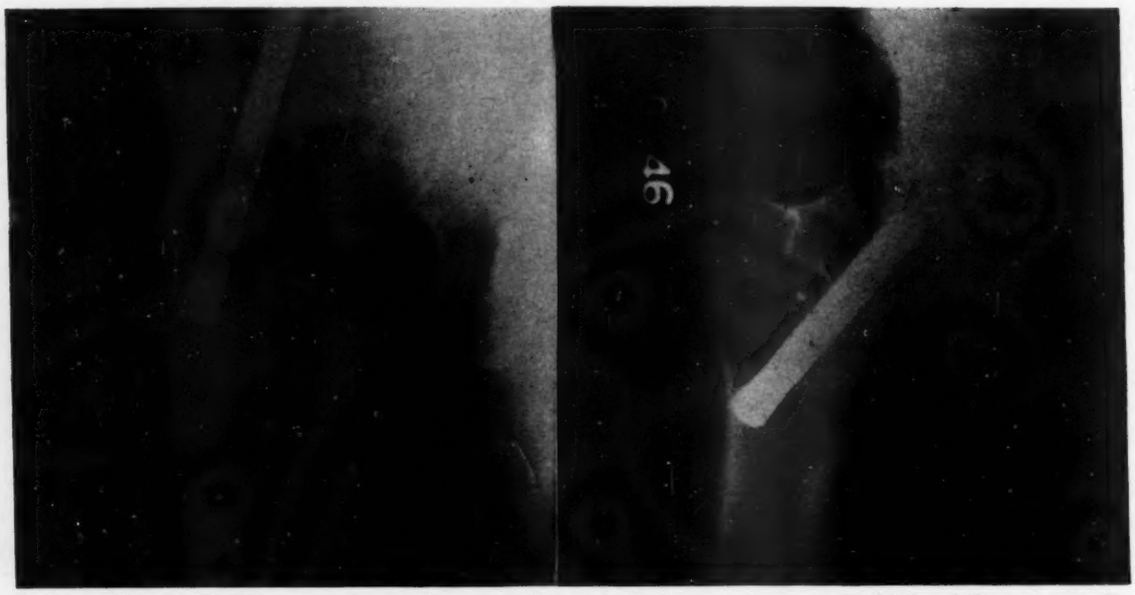


FIG. 1. A, Case F. W. failure to reduce and convert the vertical plane to a horizontal position; failure to transfix the fragments.

FIG. 1. B, nail removed one week later; radiographs four months after anterior McMurray osteotomy; stable and painless hip.

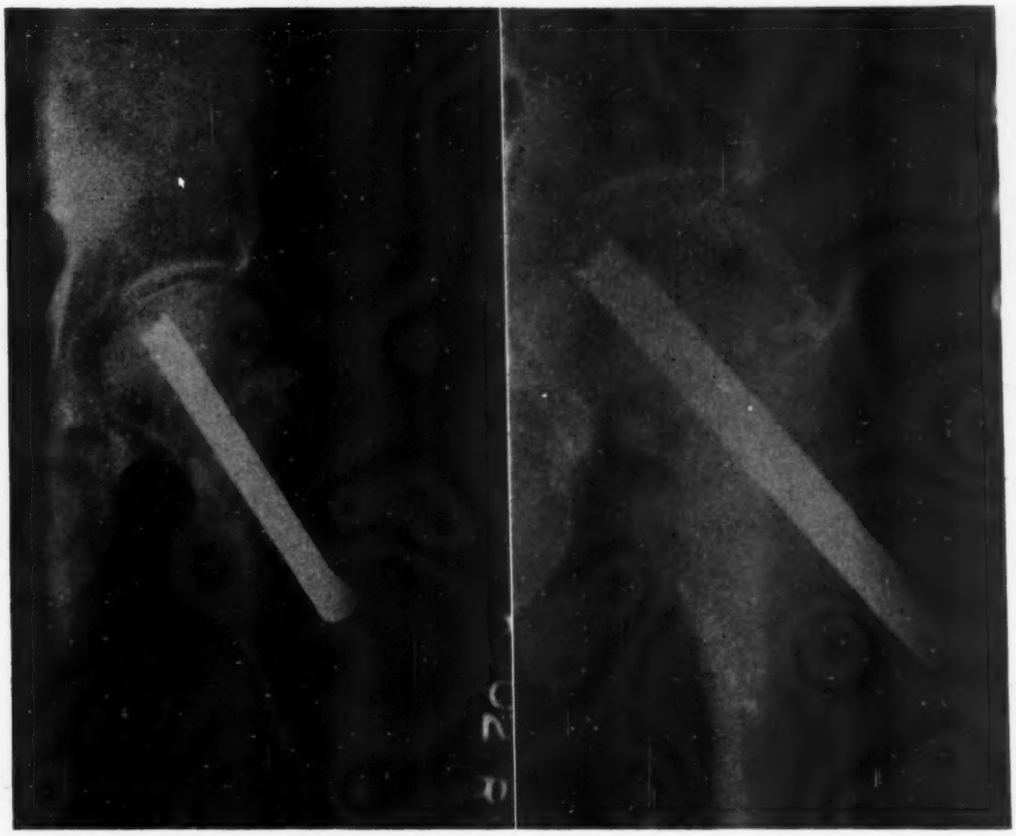
could have been prevented. Primarily, *operation should not be delayed.* Early reduction and transfixion is indicated to attempt to salvage and re-establish the continuity of the vascular bed. Secondly, *we have encountered many pitfalls* during reduction and transfixion which if prevented would probably have reduced the instances of non-union. These must have been common to others but repetition and emphasis may be helpful.

PITFALLS IN REDUCTION AND TRANSFIXION

I. Failure to reduce the fracture completely and produce a valgus pedestal for the head

II. Failure to engage or adequately transfix the proximal fragment (Figs. 1A and B, Case F. W.)

III. *Medial superimposition* of the inner aspect of both fragments. This results in medial foreshortening of the neck. This may



A B

Fig. 2. A, Case M. G. November 12, 1946, incomplete reduction, medial superimposition of fragments and external rotation of shaft. The nail transfixed both fragments on the lateral film. B, March, 1947, patient bore weight contrary to instructions; foreshortening of the neck and extrusion of base of nail.

A B

Fig. 3. A, Case E. C. sixty years; radiograph six days after injury; failure to reduce the fracture and medial superimposition of the fragments, October 18, 1946. B, April 10, 1947, increased medial foreshortening, increased density fracture site, base of nail extruding.

follow (1) incomplete reduction, (2) failure to maintain oblique non-serrated fragments in a corrected position or (3) tilting the proximal fragment by an oncoming nail due to failure to fix the fragments adequately by strong guide wires. (Figs. 2A and B, Case M. G., and 3A and B, Case E. C.)

IV. *Insertion of nail in outer third of the proximal fragment.* The stress and strain causes angulatory pivoting and pressure necrosis. The nail erodes the head and emerges from the proximal fragment.

V. *Extracting and reinsertion of too long, too short or inaccurately inserted nail* impairs the viability of the head and head (eighteen cases)

VI. Inadequate engagement of the proximal fragment by too short a nail may result in the nail extruding from the proximal fragment

VII. Penetration of the articular surface by too long a nail causing erosion of the cartilage

VIII. *Too early weight bearing.* This applies to the cases in which the fragments have been properly transfixed in a valgus position as well as to the inadequately engaged proximal fragment.

IX. *The routine transfixion of the head and acetabulum* by a guide wire not infrequently directed toward the ligamentum teres, to prevent rotation of the head by the oncoming nail, *should be abandoned.* This procedure may impair the circulation or damage the cartilage. The procedure should be replaced by two parallel strong non-calibrated guide wires into the head.

X. Calibrated indented guide wires should be avoided because the indentations impair their tensile strength. The break occurs at the site of an indentation from the impact of the oncoming nail (1) if the fragments had not been stabilized by impaction or (2) the extremity had not been rigidly immobilized on a fracture table (four cases)

XI. A screw should not be used to transfix the base of the Smith-Petersen nail to the shaft. If foreshortening does occur, it is obviously more desirable that the base of the nail extrude than to allow the nail to penetrate the articular surface gradually.

XII. *Fracture improperly selected for transfixion:* An inadequately immobilized fracture of two weeks' duration may have impaired the blood supply of the head. Considerable absorption of the neck may be present. *Osteotomy is indicated* because the absorption of the neck may be progressive even though transfixion appears satisfactory. This may result in complete absorption of the neck with: (a) the nail straddling both fragments Figs. 4A to D, Case S. S.); (b) erosion with penetration of the nail through the head (Figs. 4A to D, Case S. S.); (c) extrusion of the nail from the shaft with foreshortening of the neck (Fig. 5A, Case E. K.)

XIII. Infection and circulatory disturbance leading to absorption of the head and neck (Fig. 6, Case M. L.)

FACTORS FOR SATISFACTORY TRANSFIXION

To enhance the successful transfixion we wish to reiterate that the following conditions are indispensable:[6,7] (1) Immediate reduction, (2) immobilization on a fracture table to maintain reduction and eliminate the possible change in position of the fragments during the variable duration of the operative procedure, (3) the use of two strong non-calibrated $\frac{3}{16}$ inch guide wires inserted $1\frac{1}{2}$ cm. apart and parallel to each other to stabilize the reduced proximal fragment; the use of the best positioned guide wire for the insertion of the properly selected cannulated Smith-Petersen nail or similar cannulated device which incorporates the principle of preventing angulation, shearing or rotation and (4) the confirmation of all three steps by good lateral and antero-posterior roentgenograms.

ALTERNATIVE INTRA-ARTICULAR ARTHROTOMY AND OSTEOTOMY

If the good reduction and good transfixion cannot be achieved and pitfalls seem inevitable, the fracture site should be exposed through an anterior incision and transfixion should be attempted. This is by no means a simple procedure, particularly if previous attempts have failed. It should be reserved for patients in the younger age group. While the fracture surfaces are exposed and the fragments may be hooked

into position, the operation is time consuming as it also requires radiographic control to transfix the fragments accurately with the cannulated nail. The visual realignment of the fragments on their inner anterior aspect may be misleading. There may be superimposition of the inner aspect of both fragments with a resulting poor pedestal. Failure to obtain and maintain a satisfactory position of the fragments or failure to hold and transfix the fragments requires that the surgeon decide whether or not (1) to continue further attempts at correction and transfixion, thus involving greater risk to the patient and further jeopardizing the neck and head by repeated insertions of the nail or (2) to defer the operation until another day and again attempt to reduce and accurately transfix the fragments. From our observation of unsuccessful repeated attempts we believe that a visual osteotomy should be performed at the first operation if the objectives cannot be obtained and the condition of the patient is satisfactory. Otherwise the visual osteotomy should be performed as soon as the patient has satisfactorily recovered from the first operation and the reaction of the tissues to the additional trauma had subsided, usually within ten to fourteen days. The Leadbetter cervical axial osteotomy was satisfactorily performed in five cases in the older age group in which reduction and transfixion could not be satisfactorily achieved. McMurray performed twenty-three subtrochanteric osteotomies for recent fracture and bony union followed in all.[8]

M. D., a female, seventy-five years old, sustained a high transcervical fracture on January 2, 1947, with considerable upward displacement and outward rotation of the shaft. The fracture was reduced and transfixed with a 3¾ inch Smith-Petersen nail. The films on January 4th revealed the shaft and head transfixed at an angle of 125 degrees, the shaft externally rotated and some superimposition of the fragments. The films on January 20, 1947, revealed the nail extruding from the head. On January 28, 1947, a Leadbetter-McMurray-Brackett osteotomy was performed and the extremities were immobilized in plaster. In April, 1947, the cast was removed. There is osseous union and good general alinement of the fragments. (Figs. 7A to C.)

TREATMENT OF UNUNITED FRACTURE OF THE NECK OF THE FEMUR

In 1936, McMurray[7] reported twenty-seven cases of ununited fracture of the neck of the femur treated by a bifurcation operation. This was based on the suggestion of Lorenz that the stability of the hip could be restored by bringing the support under the center of the acetabulum. Schumm,[10] in 1937, reported his experience with the Schanz osteotomy in a series of twenty-eight cases in which he claimed increase in stability of the hip and a definite relief from pain and fatigue. In 1940, Reich[11] advocated a guide wire, pin or screw in the direction of the proposed osteotomy and an anteroposterior roentgenogram to determine the exact level of osteotomy. Twenty-two of his twenty-six patients were able to get about with little difficulty or discomfort. Speed and Smith,[12] in 1940, obtained solid osseous union between the head and neck of the femur in fifteen of thirty cases following osteotomy and they indicated that osteotomy may be performed in preference to reconstruction.

The encouraging experience of these surgeons and the less formidable nature of the oblique osteotomies prompted us to accept the McMurray operation and to employ a guide wire to determine the desired location of the proposed osteotomy as advocated by Reich. Eight such operations were performed and the results are tabulated in Table v. The "simplicity and absence of shock" which McMurray claimed was substantiated by our experience. The procedure offered the simplest approach to restoring a normal anatomic and physiologic pedestal for the head. While our results were not uniformly satisfactory, they were encouraging in five cases in which union and stability were obtained.

Leadbetter[13] made an extremely valuable contribution by further simplifying the operative procedure when in 1944 he proposed an osteotomy high in the cervical axis through an anterior approach. This operation offers advantages as follows: (1) Any uncertainty as to the proper level, direction or rotation of the osteotomy is eliminated. (2) Visual inspection of the fracture site to determine the extent of absorption of the neck, the state of viability of the head, the extent and nature of the interposed tissue is possible. There is also opportunity to remove this tissue. (3) Visual mobilization of the shaft, which may have been displaced upward and be held by contracted muscles thereby sacrificing the minimum amount of length, is also possible. (4) The necessity of using a guide wire and taking re-

FIG. 4. A, Case S. S. sixty-nine years old. Fractured hip six weeks before admission; position of fragments December 2, 1943, some absorption of the neck.

FIG. 4. B, May, 1944, progressive absorption of the neck; five months after transfixion; tip of nail encroaching closer to articular surface; no pain?

peated roentgenograms to determine the site of a guide wire or osteotome is obviated. (5) The procedure is less time-consuming and therefore less shocking to the patient. (6) A more exact anatomic and surgical approach to furthering the six criteria which Leadbetter considered ideal for repair of non-union is offered. These are: (1) preservation of the articulation of the head and acetabulum, (2) establishment of a normal acetabular thrust, (3) creation of positive pressure by a true valgus, (4) allowance for contact of cancellous bone surfaces, (5) preservation of adequate circulation and (6) production of minimal shortening.

In April, 1944, Rowe and Ghormley[14] reported that thirty-four Brackett operations had been performed at the Mayo Clinic and that good results were obtained in twenty-three or 67.7 per cent of the cases. They also reported good results in ten of eleven cases which they internally fixed with a Vitallium screw driven

Fig. 4. c, October, 1946, nail beyond articular surface; patient has been getting about on crutches; had pain four weeks.

Fig. 4. d, February, 1947, three months after combined operation; films taken in abduction and adduction; in May, 1947, no pain, firm union.

through the transplanted trochanter and the shaft into the head fragment.

The most frequent cause of failure which we have encountered in both the intra-articular and extra-articular osteotomies was slipping of the shaft. Weekly radiographic examinations were made while in plaster to detect the slightest change in the position of the shaft. In two cases the loss was detected during the first week after the operation and in both cases wedging of the plaster spica restored the shaft to position. Other observers reported slipping of the shaft as the most frequent cause of failure following McMurray or Schanz osteotomies. Rowe and Ghormley[14] and Magnuson[15] reported that the most frequent cause of failure with the Brackett operation was slipping of the shaft.

McMurray—Leadbetter—Brackett Procedure

In eleven patients the anterior incision was employed. In four the Leadbetter cervical axial osteotomy was performed. In seven we combined the McMurray, Leadbetter osteotomy with a partial Brackett procedure by scooping out the inner component of the head and implanting the rounded or squared inner component of the osteomotized shaft into the

FIG. 5. A, Case E. K. Smith-Petersen nail inserted February 3, 1944, fifteen days after fracture; films taken in abduction and adduction three years later, March, 1947; absorption of the neck; nail pivoting on head; increased density of shaft, nail extruding and foreshortening of the neck; pain, shortening and no stability.

FIG. 5. B, combined operation March, 1947, plaster spica three months; films July, 1947, corrected position maintained; no pain.

FIG. 6. Case M. L. The patient, sixty years old, sustained subcapital fracture April 26, 1943; admitted May 13th; Smith-Petersen nail inserted May 14th; nail extruded from the head; reinserted June 1st, infection with drainage for many months. The nail was removed November 15, 1943. Gradual absorption of head and neck took place. Film May, 1945, revealed base of neck fused to outer rim of acetabulum.

partially scooped out proximal fragment. The pointed inner portion of the sectioned greater trochanter is wedged between the under outer surface of the head and the shaft (1) to augment the blood supply to the head and (2) to prevent rotation of the head and outward displacement of the shaft. (Figs. 8 A, B and C.)

The muscular attachments of the greater trochanter are sutured to the muscles of the distal fragment. We have not transfixed the fragments with a screw as advocated by Rowe

and Ghormley. The double spica does not include the ankle. It is believed that some absorption takes place during the first and second week at the sight of implantation of the head and shaft. By omitting the plaster from the foot, sustained impaction of the head and shaft is not impeded. Leadbetter bivalved his casts in four weeks and removed them in eight weeks. We have continued immobilization in plaster eight to fourteen weeks believing that the pain and discomfort in the thigh is less and that osseous union may be more stable. To date there has been no untoward effects from immobilization in plaster.

TABLE II
SUMMARY

	Operations	Shaft Slipped		Result			
		Entirely	Partially	Good	Fair	Poor	Died
Bone graft and Smith-Petersen nail	4	..	..	..	1	2*	1
Whitman reconstruction	3	..	3	..	2	1	
McMurray-Lorenz extra-articular osteotomy	8	2	2	3	2	2	1
Intra-articular osteotomy, Leadbetter-McMurray	4	..	2	2	1	1	
Leadbetter-McMurray-Brackett	7	1	3	4	1	1	1
	26	3	10	9	7	7	3

* One patient subsequently had an extra-articular osteotomy with satisfactory result.

Results. There were twenty-six operations on twenty-four patients. Of the twenty-four patients, seventeen were females and seven were males. The average age at the time of operation was sixty-five years; the youngest was thirty-eight years and the oldest eighty-seven. The average period of non-union was sixteen months, the shortest was two months and the longest was nine years. (Table II.)

Fifteen patients had previous operations. In twelve the Smith-Petersen nail gradually extruded from the head either from angulatory pivoting or necrosis of the head or the nail had not adequately engaged the proximal fragment. In three cases the nail straddled the head and shaft with progressive absorption of neck. Nine patients had no previous operation; one had two ununited fractures.

The results of four cases treated by bone graft and Smith-Petersen nail are shown in Table III. The average duration of non-union was nine months, the shortest two and the oldest fourteen months. The youngest was thirty-eight years old and the oldest seventy. One patient died. The result was fair in one and poor in the two others. However, one patient whose fibular graft broke and the nail extruded three months after the operation was again operated by the McMurray extra-articular procedure which resulted in a satisfactory stable and painless hip. His case is also included in Table V.

Results of three cases treated by Whitman reconstruction are shown in Table IV. The duration of non-union was three, two and nine months and their ages sixty-nine, sixty-seven and sixty-three years, respectively. The results in two were fair and in the other poor. There was partial to gradual complete extrusion of the shaft, pain and lack of stability.

Results of nineteen hips that were osteotomized for non-union are as follows: The average duration of non-union was nineteen months, the shortest was three months and the longest nine years. Two of the patients died; one with Parkinsonian disease died on the seventeenth day after a McMurray extra-articular osteotomy from a coronary occlusion. The other, R. K., sixty-eight years old, was in poor condition at the time of admission. Her operation was deferred until several transfusions helped to improve her condition. The fragments slipped and she never rallied sufficiently after the Leadbetter-Brackett operation to permit wedging of her cast. She died four weeks after the operation.

Two of the seven who survived the extra-articular osteotomies had poor results while five had osseous union and fairly stable, painless hips. (Table V.)

FIG. 7. A, Case M. D. seventy-five years old, fracture transfixed January 2, 1947, the day of admission; films reveal the shaft externally rotated and superimposition of rotated fragments.

FIG. 7. B, eighteen days later nail has extruded out of head.

Of the ten patients who survived the intra-articular osteotomies, four had McMurray procedures according to the technic advocated by Leadbetter. Two of these had satisfactory results. The result is fair in one and poor in the other because the shaft slipped although there is some stability in both. (Table VI.)

In four of the seven intra-articular osteotomies, in which the Leadbetter-McMurray-Brackett principles were applied, the results are satisfactory. One patient, seventy-five years old, who had an unsuccessful Lorenz osteotomy in another institution, was again operated upon one year later. There was complete absorption of the neck and marked upward displacement of the shaft. A satisfactory position was maintained for ten weeks with the aid of a hook incorporated in plaster. Films taken without plaster in abduction and adduction revealed the shaft pivoting on the head. This we attributed to too oblique an osteotomy and insufficient bony contact. Films eight months later reveal some new bone but the shaft still pivoted on the head. (Figs. 10A, B and C, Case F. H.) One patient died; another was operated upon too recently to evaluate.

There was some stability even in the presence of a shaft that slipped from under the head after the osteotomy in practically every case. In Case A. P., who had both a three months and a nine year old ununited hip, the shaft slipped following the osteotomy on the three months old ununited hip; the shaft rested under the rim of the acetabulum and the patient walked

Fig. 7. C, combined osteotomy performed January 28, 1947; spica cast for three months, films in abduction and adduction April, 1947, firm union, no pain, good weight-bearing hip.

without pain and bore weight with the aid of crutches. (Figs. 9A, B and C.)

Four cases deserve reporting because each presented different findings:

CASE REPORTS

Case G. M., eighty-seven years of age, in excellent physical condition, sustained her fracture in June, 1945. She was admitted with complete absorption of the neck and a viable head. In December, 1946, a combined osteotomy and then ten weeks in plaster resulted in a united fracture and a stable and painless hip. In May, 1947, there was no pain and the patient is very active. This is our best result. (Figs. 11A and B.)

Case A. P., a fifty-nine year old woman, sustained a fracture of her right hip in March, 1946. She was admitted in July. In August, a Leadbetter-McMurray operation was performed. The shaft slipped. The patient also had an ununited fracture of the left hip which she sustained nine years ago. She lived on a barge for the nine years. Radiographic examination revealed complete absorption

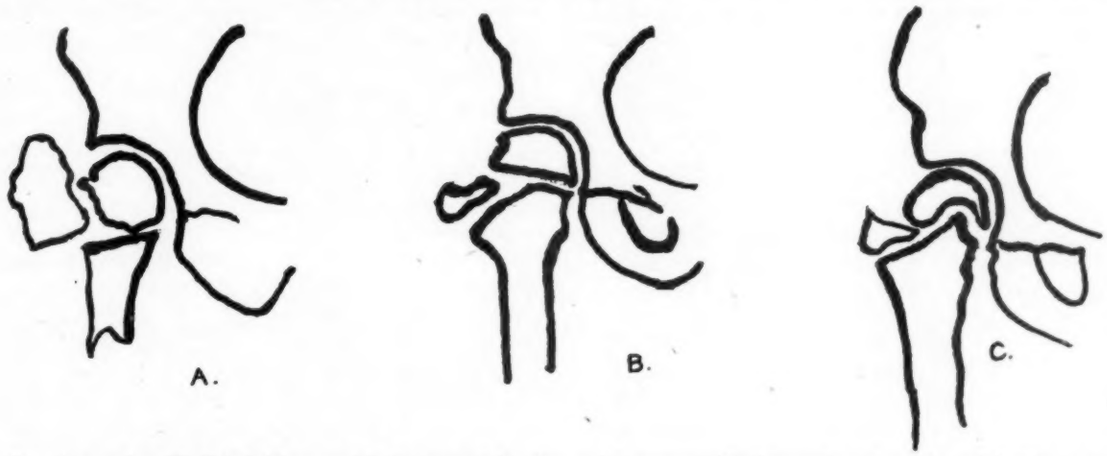


Fig. 8. A, after T. P. McMurray (*J. Bone & Joint Surg.*, 18: 319, 1936). Line of section of modified Lorenz osteotomy and displacement of lower fragments; B, after Leadbetter, G. W. (Cervical-axial osteotomy of the femur. *J. Bone & Joint Surg.*, 26: 714, 1944). Position of the fragments following visual osteotomy. C, combined McMurray-Leadbetter-Brackett procedure; scooping out the inner half of the head and implanting the osteotomized shaft and wedging the sectioned trochanter between the fragments.

TABLE III

FOUR CASES OF UNUNITED FRACTURES OF THE NECK OF THE FEMUR TREATED BY A BONE GRAFT AND SMITH-PETERSEN NAIL

Case	Age	Date of Fracture	Previous History	Date of Operation	Operative Findings	Postoperative Course	Result
W. C.	70	Jan. 1941	Russel traction in another hospital	Sept. 1941	Viable head; partial absorption of neck	3 months later nail extruded; 3 months later fibula graft fractured	Poor; non-union neck; some new bone
M. C.	55	Aug. 1942	No treatment	Oct. 1942	Partial absorption of neck—head viable	Infection Welchi subticus; nail removed 5 months later; one month later coronary infarction	Died
A. K.	54	April 1942	No	Aug. 1942	Questionable viability of head—partial absorption of neck	3 months later fibula graft broke and nail extruded; *osteotomy* (McMurray) Nov. 1942, cast	Satisfactory stable painless hip after osteotomy
R. Mc	38	Sept. 1941	Snapped hip on telephone pole; SPN* inserted after 2nd attempt	Nov. 1942	Nail bridging gap 1½ inches between head and shaft	3 months later graft broke in spica nail removed Jan. 1945, exuberant new bone	Fair; partial subluxation of head; exuberant new bone; hip not stable

* SPN = Smith-Petersen nail.

TABLE IV

THREE CASES OF UNUNITED FRACTURES OF THE NECK OF THE FEMUR TREATED BY WHITMAN RECONSTRUCTION

Case	Age	Date of Fracture	History	Date of Operation	Operative Findings	Cast	Shaft out of Acetabulum	Course	Result
B. C.	69	Dec. 1942	SPN* in another hospital; extruded	March, 1943	Some absorption of neck; viability of head questionable	6 wk.	30–40%	July, 1944 Fr. of shaft; shaft partially extruded	Fair ?
L. G.	67	Dec. 1941 ?	Traction	Jan. 1942	Absorption of entire neck; head viability questionable	6 wk.	20%+?	Stability ?	Fair ?
G. S.	63	July, 1945	SPN* 4 wk. after fracture; nail extruded	Apr. 1946	Absorption of neck; viability of head impaired	2 mo.	50%+	Shaft gradually extruded; pain	Poor

* SPN = Smith-Petersen nail.

of the neck and increased density of the distal third of the head. In October, 1946 the combined Leadbetter-McMurray-Brackett operation was performed. Most of the marble white bloodless distal inner two-thirds of the head was scooped out. A bone hook encircling the shaft was utilized to straddling both fragments. In December, 1946, the nail had eroded the head. A Leadbetter-McMurray-Brackett operation was performed and a spica was applied for three months. In May, 1947, union was firm in abduction and adduction. The hip was stable and she had no pain. (Figs. 4A to D.)

TABLE V

EIGHT CASES OF UNUNITED FRACTURES OF THE NECK OF THE FEMUR TREATED BY EXTRA-ARTICULAR OSTEOTOMY

Case	Age	Date of Fracture	History	Date of Operation	Operative Findings	Cast	Shaft Slipped	Postoperative Course	Result
P. B.	53	June, 1944	SPN*—in another hosp., nail extruded decubitus ulcer	Dec. 1944	Viable head; some absorption of neck	3 mo.	50%	7 mo. later 2 screws fixed trochanter to pelvis	Fair; 3 yr. with cane
B. C.	46	Mar. 1944	SPN* 3/21/44 walked; nail extruded	April, 1945	Viable head; absorption of neck	3 mo.	40%	Dec. 1945, fracture of other hip	Satisfactory; 16 mo. walks with cane
R. H.	74	Jan. 1943	SPN*—4 mo. later nail extruded	May, 1944	Head viable; absorption of neck	3 mo.	No	Uneventful	Satisfactory; stable; painless
F. I.	60	Nov. 1944	SPN*—Parkinson; pin gradually extruded	May, 1945	Head viable; some absorption neck	+	....	17th day heart attack	Died
T. M.†	61	Oct. 1941	SPN*—nail straddling fragments	Dec. 1943	Absorption of neck; head viable	M. B. +	No	Blade did not engage head satisfactorily	Poor; nonunion
B. R.	78	Oct. 1944	SPN*—nail extruded	Jan. 1945	Absorption of part of neck; head viable	3 mo.	No	Uneventful; followed 6 mo.	Fair; union
E. W.	70	June, 1945	SPN* extruded	Oct. 1945	Absorption of neck; head viable	2 mo.	80%+	Fr. ankle; fr. femur lower end; can raise heel	Poor
A. K.‡	54	April, 1942	SPN* and fibula graft (8) 1942 graft broke, nail extruded	Aug. 1942	Questionable viability of head; partial absorption	2 mo.	No	Stable; painless	Satisfactory

* SPN = Smith-Petersen nail.

† T. M.—Moore Blount Blade Plate.

‡ A. K.—Also listed on Table treated by SPN and graft.

maintain the shaft in position and incorporated in plaster. The cast was removed after three months. Union of the left hip is firm as indicated radiographically in the abducted and adducted position. The head of the left femur, however, is dense. She left the hospital in May, 1947; both hips were stable and she had no pain. (Figs. 9A, B and C.)

CASE S. S., a sixty-nine year old female, sustained a fractured hip six weeks before admission to Bellevue Hospital in November, 1943. A Smith Petersen nail transfixed both fragments. The neck continued to absorb and soon the nail was found

CASE E. K., a forty-two year old female, sustained a subcapital fracture on January 18, 1944. She was transferred from another hospital. On February 3rd, a Smith-Petersen nail was inserted. The subsequent film revealed the angle of the shaft and head transfixed at 130 degrees with 80 per cent apposition of the fractured surfaces on the anteroposterior view and 60 to 70 per cent on the lateral. She was not seen for three years at which time the films suggested some collapse, irregularity of the articular surface, questionable increase in the density of the head and some foreshortening

of the neck pivoting around the nail when the thigh was abducted and adducted. On March 25, 1947, operation revealed the shaft displaced backward and upward and the head pivoting on the nail. There was considerable dense granulation tissue between the fragments but the head was viable. After removal of the nail and scooping out of the inner third of the head, the osteotomized shaft was implanted into the inner aspect of the head. The greater trochanter was imbedded between the shaft and outer half of the head, sutured into position and a double plaster spica was applied.

TABLE VI

TEN CASES OF UNUNITED FRACTURES OF THE NECK OF THE FEMUR TREATED BY INTRA-ARTICULAR OSTEOTOMY

Case	Age	Date of Fracture	History	Date of Operation	Operative Findings	Leadbetter McMurray	Leadbetter Brackett	Cast	Shaft Slipped	Postoperative Course	Result
P. F.	69	1937	Treated in plaster in 1937; 8 mo.	Sept. 1942	Absorption neck; head viable	*	....	2 mo.	No	Firm union	Satisfactory
G. M.	87	June, 1945	Treated with traction in another hospital	Dec. 1946	Absorption neck; head viable	..	*	10 wk.	No	Slight knock knee; firm union	Satisfactory
F. H.	75	Nov. 1945	Lorenz osteotomy Dec. 1945, in another hospital	Oct. 1946	Absorption neck; head viable	..	* and hook	3 mo.	40%+	Knock knee some union	Poor
R. K.	68	Mar. 1945	Traction in another hospital	Dec. 1946	Absorption neck; head viable	..	*	*	100%	Poor general died 4 wk. later	Died
M. P.	70	Aug. 1946	Cast 8 wk. in another hospital	Dec. 1946	Absorption neck; head viable ?	..	*	3 mo.	30%+	Firm union	Satisfactory
A. P.	59	Mar. 1946	Fell on barge; fr. rt hip—4 mo., no treatment	Aug. 1946	Absorption neck; head viable	*	....	2 mo.	80%+	.....	Fair
A. P.	59	1937	Fell on barge 9 yr. ago; left; no treatment	Oct. 1946	Absorption neck; part of head avascular	..	* and hook	3 mo.	No	Firm union	Satisfactory
S. S.	69	Nov. 1943	Fr. 6 wk. SPN;* gradual absorption neck; nail straddling fragments	Dec. 1946	Absorption neck; necrosis head at site of nail; nail straddling fragments	..	*	3 mo.	20%–30%	Firm union	Satisfactory
V. T.	75	May, 1946	SPN* early weight bearing; eroded and extruded	Aug. 1946	Absorption neck; head viable	*	....	3 mo.	40%+	Pain; lack of stability	Poor
M. T.	66	Nov. 1944	SPN* extruded; reinserted; extruded	April, 1946	Absorption neck; head viable	*	....	3 mo.	No	Firm union	Satisfactory
E. K.	42	Jan. 18, 1944	SPN*—2/3/44; non-union	March, 1947	Absorption neck; head viable	..	*	3 mo.	No	.....	?

* SPN = Smith-Petersen nail.

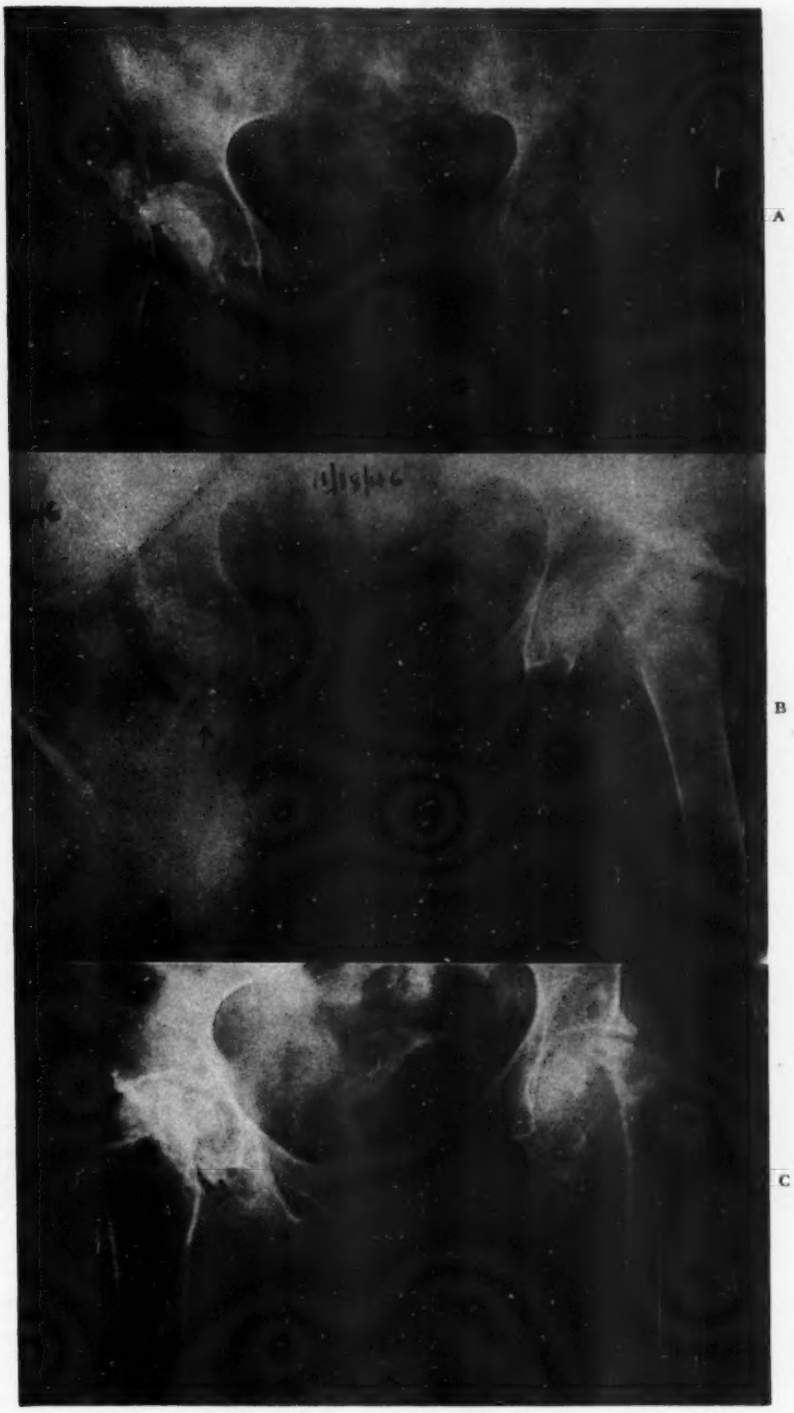
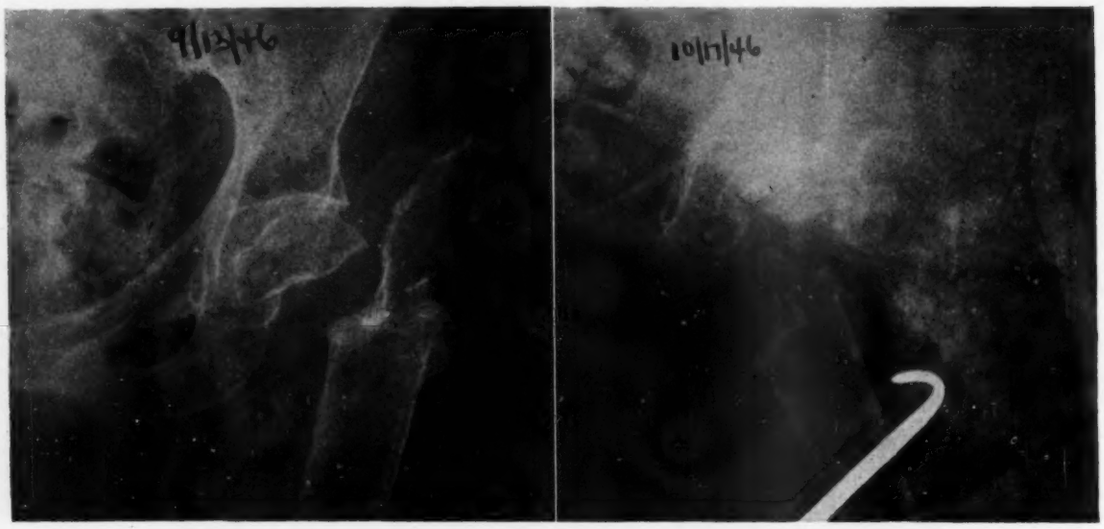


Fig. 9. A, Case A. P. fifty-nine years old; ununited fracture of left hip three months and ununited fracture of the right hip of nine years' duration; avascular necrosis distal half of head and increased density of intertrochanteric region; upward displacement of shaft. B, combined operation; hook to maintain shaft in position is incorporated in the plaster spica; C, five months after combined operation of the left hip; union; increased density of the remaining portion of head; no pain; stable hip.



A B

FIG. 10. A, Case F. H. seventy-five years old, sustained fracture in November, 1945; Lorenz osteotomy in December, 1945, in another institution; admitted to Bellevue Hospital September, 1946. Complete absorption of the neck and marked upward displacement of the shaft. B, October 8, 1946, anterior combined operation with hook incorporated in plaster to prevent outward displacement of shaft.

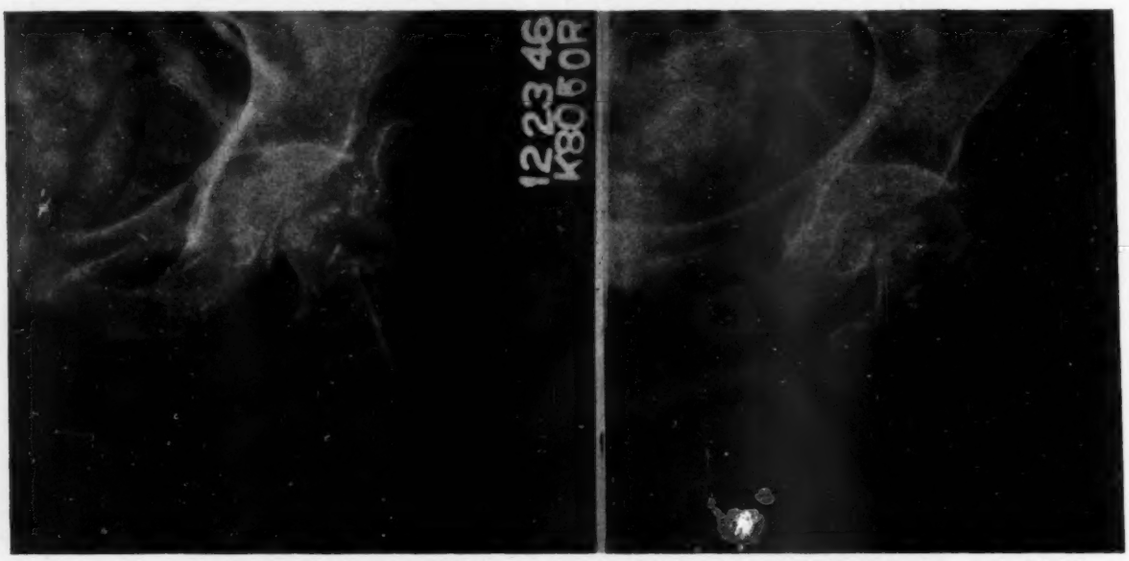


FIG. 10. C, December 23, 1946, afer ten weeks in plaster, showing shaft pivoting in abduction and adduction; in June, 1947, more new bone, shaft still pivots, some stability present.

The subsequent films every two or three weeks revealed that position of the fragments has been maintained. (Figs. 5A and B.)

SUMMARY AND CONCLUSIONS

Pitfalls in reduction and internal transfixion accounted for sixteen ununited fractures in 146 acute fractures of the neck of the femur. Ten other ununited fractures had no treatment.

The high incidence of non-union can be largely prevented or at least materially reduced by early and accurate reduction and transfixion. By eliminating the pitfalls in the procedure one can salvage some of the blood supply of the disrupted capsule, limit and prevent shearing, rotation and angulatory pivoting.

If the objectives of proper transfixion cannot be achieved and an unsatisfactory result seems inevitable, a visual osteotomy is indicated.

Of twenty-six ununited fractures of the neck of the femur, four were treated with a bone graft and Smith-Petersen nail, three by a Whitman reconstruction operation and nineteen by oblique osteotomies, of which eight

Fig. 11. A, Case G. M. eighty-seven years old, sustained fracture in June, 1945; admitted in December, 1946; absorption of neck and upward displacement of shaft.

Fig. 11. B, combined operation December, 1946, ten weeks in plaster; films in abduction and adduction; in May, 1947, pushed walker around; no pain; slight valgus at the knee.

were by the extra-articular and eleven by the intra-articular approach.

The anterior cervical-axial osteotomy, as advocated by Leadbetter, offers a more accurate, less time-consuming procedure in carrying out the Lorenz-McMurray principles.

To obtain the overall objective of maintaining the osteotomized shaft under the head until osseous union was complete we employed the Leadbetter-McMurray principles with a partial Brackett procedure.

The period of observation of the osteotomized hips is too short to evaluate the ultimate results. The immediate results in some of the cases are gratifying. It is nevertheless our thesis that the prevention of non-union should be the underlying objective in the treatment of the ununited fracture of the neck of the femur.

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TECHNIC OF HIGH SUBTROCHANTERIC OSTEOTOMY

E. ASBURY, M.D.
Cincinnati, Obio

THE increasing use of osteotomy in both old and fresh fractures of the neck of the femur makes it necessary to perfect a better method of performing this important procedure. The technic of the operation is usually dismissed with the statement that a high osteotomy was performed, followed by inward displacement of the shaft of the femur. Through a study of the factors causing several poor results as well as the observation of two particularly successful cases (resulting from accidental variations in the usual method of performing the operation), an improved technic has now been evolved. It is hoped that further application and study of this method will make it more useful in both old and fresh fractures of the neck of the femur. Recent communication with thirty leading fracture men as well as a study of the literature prove that we must again take stock of intracapsular hip fractures.

We all agree that pinning has been a wonderful advance. Leaving out those cases, irretrievable by any method, the percentage of good results as reported varies from 40 to 80 per cent depending on the length of time followed. Clinics located in rural areas had better results (Mayo Clinic 75 per cent) than big city charity hospitals. Vigorous old farm folk do better than ill fed slum derelicts. There is also still a wide divergence of opinion as to the best methods of pinning. By any method of internal fixation the usual causes of bad results are well known. (1) Inadequate reduction and pinning; (2) degenerated bony structure which in the aged will not support internal fixation; (3) late aseptic necrosis (or fragmentation) of the head of the femur; (4) degenerative arthritis with or without bony union and (5) too early weight-bearing on a bad mechanical line subject to shearing force.

Whatever the cause, all surgeons queried had seen a lot of bad results in cases of intracapsular fracture of the neck of the femur. Practically all stated they used some form of reconstruction operation, usually the Colonna or Brackett types, at least in the younger or more vigorous subjects, reserving osteotomy for the older group. This personal survey as well as the literature of the past few years shows an increasing number of the leading surgeons of England and America using osteotomy for all old hip fractures with bad results whether due to mal-union, non-union or degenerative arthritis. Frank Dickson,[1] Leadbetter,[2] Wallace Cole,[3] Kellogg Speed,[4] J. S. Speed (Memphis),[5] George Bennett,[6] Hermann,[7] Barney Owen,[8] McMurray[12] of England, Reich[9] and Magnuson[10] are a few who now are using osteotomy as the treatment of choice in old ununited cases. Cole and Murphy[11] have used this method instead of primary pinning while McMurray uses it exclusively in both fresh and old intracapsular fractures. A few, though not the majority, report the use of pins to hold the fragments after osteotomy. High osteotomy is more popular because of the greater chance of bony union in the original fracture, and because internal fixation of the fragments is almost obligatory with the Schanz or low osteotomy.

It is generally conceded that the well known reconstruction operations of the hip were great contributions. Diagrammatically, all can be made to look simple and efficient. In actual practice, others as well as myself have found it necessary to use these procedures only in selected cases because of conditions present at the site of fracture or because of the condition of the patient. Such procedures as the bone-peg operation or the Brackett, Whitman, or Colonna reconstructions are all formidable as to risk and difficult of execution. J. S. Speed stated that only about 60 per cent fairly good results are obtained by these large procedures even in selected cases and that 25 per cent of the favorable results are later vitiated by degenerative arthritis causing painful and restricted hip movement. Against the net 45 per cent satisfactory results from reconstruction operations used only on good risks, most men report about 80 per cent good results with osteotomy used on all types of patients and bony union was achieved in more than half of them. The only procedure showing comparable results is the rarely indicated bone-peg operation.

Advantages of osteotomy are: (1) A simple procedure suitable to practically all age groups; (2) aseptic necrosis of the head of the femur and degenerative arthritis have not been contraindications; (3) a good weight bearing line without shearing force with or without bony union is achieved. Properly executed, a strong stable hip is the probable result in the average patient; (4) revascularization of the head of the femur which has already undergone partial aseptic necrosis is not unusual; (5) about 80 per cent good results can be expected with at least 50 per cent obtaining bony union. With proper technic the percentage of bony union can be improved; (6) few late degenerative changes have been noted following successful osteotomy; (7) normal leverage of the gluteal and psoas muscles is preserved, making for stability of the hip; (8) osteotomy is useful in treatment of malum coxae senilis; (9) the period of immobilization and non-weight bearing is short. Objections to the spica cast are minimized by active muscular exercises and proper general management while the patient is in the cast. Henderson still uses a spica cast after internal fixation of fresh fractures. The author agrees with Dickson, Henderson and others, who believe that the disadvantages of casts are overrated. The rigid, twisted, hyperextended leg in the Whitman cast often causes stiffness of joints and muscular atrophy. After osteotomy the leg is in the neutral position with the knee slightly bent and the cast is worn for only eight weeks. (10) The successful universal use of any method requires: (a) that it be simple and foolproof in the hands of the average surgeon; (b) that gadgets and hardware be avoided as far as possible. (c) that there be a minimum of possible complications and (d) that uniformly good end results be obtained in the least time.

Osteotomy is a shorter operation and easier to perform correctly than pinning. No gadgets or internal fixation are necessary and there are fewer late degenerative changes to be expected. Only after a thorough trial in fresh cases, using a better technic, can we decide whether osteotomy is the treatment of choice. There seems no doubt that this method is best for the bad results following unsuccessful pinning. The author's method of performing this operation was worked out on old cases but recently has been used on four fresh fractures. Since the present method of performing osteotomy has been used, no instance of spreading or upward displacement of fragments, troublesome in earlier cases, has been encountered and so far bony union has been obtained in almost all cases.

AUTHOR'S TECHNIC OF OSTEOTOMY

Before operation and after the usual reduction of the fracture, films are made on the operating table with the leg under manual traction. The line of osteotomy is then determined. A point as near as possible to the base of the greater trochanter is selected which will allow the line of osteotomy to go very slightly upward and inward to a level through or above the lesser trochanter. The high osteotomy keeps intact the upward pull of the muscles attached to the lesser trochanter, aiding in stability and relation of the position of the fragments. The higher the osteotomy line can be made, the broader the base of the cancellous bone that can be obtained and the better the rotation of the head. Thus more of the old fracture line can be freshened and brought into contact with the lower osteotomy fragment. To prevent knock knee, a certain amount of obliquity in the osteotomy is necessary to allow about 20 degrees abduction and still have contact of the shaft with all three fragments. The greater the obliquity of the osteotomy, the more abduction required for solid contact. Since no more than 20 degrees abduction is desirable, the direction of the osteotome must be carefully guided so that the point of emergence is only slightly higher than the point of entry. The high osteotomy with a certain amount of obliquity provides a broad base of cancellous, very highly osteogenetic bone at the upper end of the shaft. Proof of the reparative quality of bone in this area is shown by the fact that non-union of intertrochanteric fractures is unknown.

Before osteotomy is done, the periosteum must be stripped from the whole circumference of the upper end of the shaft through a vertical incision below the greater trochanter. The periosteum should be stripped clear for 3 or 4 inches down on the shaft and as high as possible toward the trochanter and neck. The sheet of periosteum must be kept intact anteriorly and posteriorly. This maneuver is one of the critical points in performing successful osteotomy because after the bone is cut through and the shaft displaced inwardly, the periosteal connections between the shaft and the severed trochanter

insure that the greater trochanter is drawn snugly against the head and better contact against the shaft and greater trochanter is maintained. The three fragments can now be manually impacted in the desired position without fear that the fragments will spread apart. Union is more assured and internal fixation by pins to prevent separation of fragments is obviated. After separating and retracting the periosteum anteriorly and posteriorly, osteotomy is performed on the predetermined line, using an osteotome no wider than the shaft. The osteotome cuts through the periosteum on the medial aspect. At times it may be difficult to preserve both the anterior and posterior periosteal strips but any retained connection is valuable. An attempt is made to rotate the head of the femur with a blunt elevator so that the old fractured surface faces as much downward as possible. The fractured surface of the head can now be freshened by a small chisel. The shaft is displaced inward, using the osteotome as a combination lever and shoe horn. Often the upper inner point of the shaft impinging against the lower edge of the head of the femur can be made to aid in further rotating the head so that more of the old fracture line can be brought into contact with the shaft. In this way union is more apt to be obtained, more new bone is deposited in the line of weight-bearing, and the head is in a better position to receive weight-bearing should bony union not be achieved. In other words, complete valgus is obtained and the shearing angle between the head and neck of the femur is obliterated. The portion of the head lying directly above the displaced shaft and as much of its old fractured surface as possible is now further freshened with the osteotome and pieces of bone from the osteotomized margins of the trochanter and shaft are forced into or around the old fracture area. Before closure of the wound, a check up film is made to be sure the shaft has been displaced sufficiently inward and impacted solidly against the underneath margin of the rotated head.

A double pica cast to the toes of the affected leg and the knees of the good leg is applied. The body portion of the cast need only embrance the pelvic region and can be cut down in front to a point below the level of the navel. After soreness from the operation has subsided, the patient is taught to contract actively all muscle groups systematically, exercising five minutes of each waking hour. At the end of six weeks the cast is bivalved and more vigorous exercises permitted. The entire cast is removed at the end of eight weeks and after a few more days of bed exercises, the patient is started in a walker or on crutches with gradually increasing weight-bearing. From this point progress will vary with each case but all are encouraged to abandon walking aides as soon as possible.

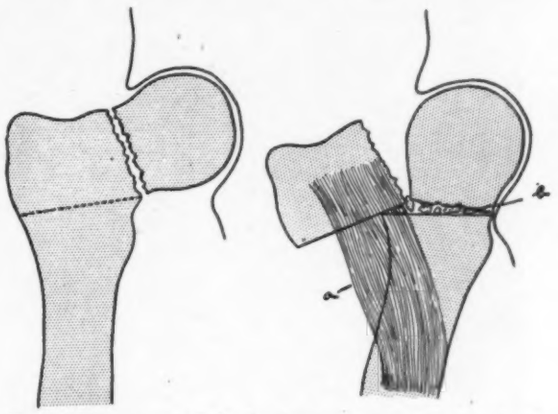
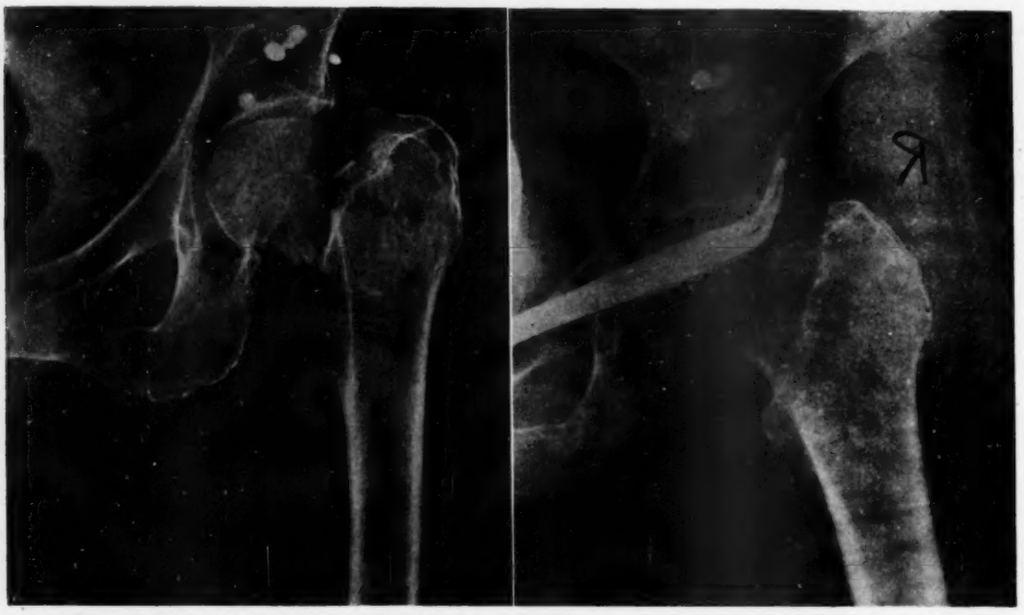


FIG. 1. Diagrams of the author's osteotomy showing *a*, retained periosteal connection between greater trochanter and shaft; *b*, bone fragments and rotation of the head of the femur.

USE OF OSTEOTOMY IN FRESH FRACTURES

Since McMurray's report about ten years ago, several men have begun to use osteotomy for fresh fractures of the neck of the femur. Murphy has reported ten cases and Wallace Cole states the method should be conceded a greater place in the treatment of this fracture. Whether we shall abandon internal fixation in favor of this procedure will require more experience. The greater danger of infection and fragmentation of the head as well as the longer period of non-weight-bearing and higher percentage of degenerative arthritis are factors arguing against internal fixation.

Points in favor of osteotomy are: (1) Complete valgus position and elimination of the shearing angle is achieved, with only about one half shortening of the leg; (2) better vascularization of the head and less danger of late arthritis and aseptic necrosis can be expected; (3) osteotomy is technically easier in fresh fractures than in old cases because the shaft can be displaced inward and the head rotated more easily. Performed by the technic previ-



A B

FIG. 2. A, fresh fracture of the neck of the femur; B, fracture reduced.

FIG. 2. C, completed osteotomy.

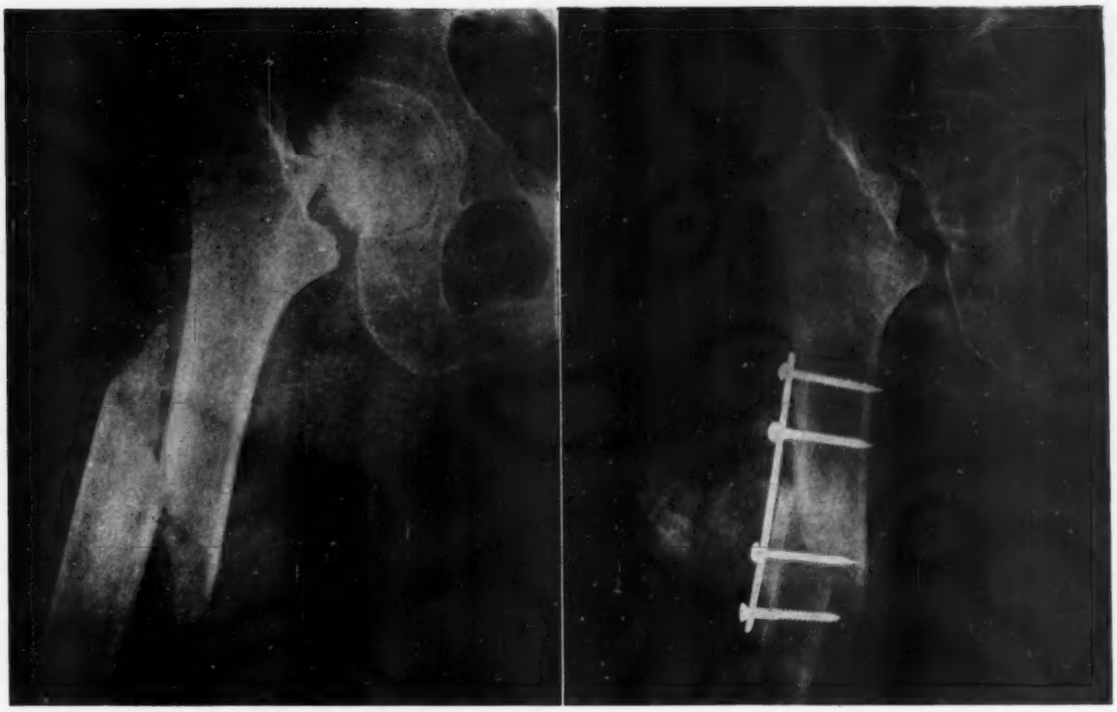
ously described, the continuity of periosteum and the pull of the common muscles attached to the osteotomized fragments tends to produce snug apposition of all three fragments without internal fixation. (4) The results so far reported have been good. The average shortening has been about ½ inch and hip joint motion with the exception of full adduction has been satisfactory. My own cases are too recent and too few (four cases) for final report but it is our intention to continue the use of the method.

COMMENT ON AUTHOR'S CASES

This report is based on the following personal experiences: (1) nineteen osteotomies for old intracapsular hip fractures, (2) four osteotomies for fresh intracapsular fractures upon which it is too early to report, though three seem to have a good result with bony union and (3) four osteotomies for malum coxae senilis without fracture.

A statistical study of these cases would be worthless and misleading. There were a number of bad results among the earlier osteotomies. With a better mechanical and physiologic conception of the problem, the results have been more satisfactory. This group of cases is too small for dogmatic conclusions but the impression gained is that fairly good restoration of function, usually with bony union, can be expected with osteotomy properly performed.

Malum coxae senilis is a form of degeneration in the head of the femur, probably due to a partial loss of blood supply. Observing revascularization in a partially dead head of the femur following osteotomy for non-union, it was decided to try this procedure for malum coxae senilis. The only variation in technic is that the osteotomy is slightly more oblique and the inner margin of the shaft is displaced inward always beneath the lower margin of the acetabulum. One patient is completely



A B

Fig. 3. A, old fracture of neck of femur with non-union and fresh fracture of shaft; B, preliminary repair of shaft fracture.

relieved four years after operation, one is improved and the other two are unimproved. These results are not spectacular but the intention is to use the method in a larger series. It must be admitted that my own experience with other operations for this condition have been disappointing. The Australian procedure, consisting of making multiple drill holes through the trochanter into the head to encourage new blood supply, has not achieved its objective in my hands but helped suggest the use of osteotomy.

SUMMARY AND CONCLUSIONS

1. The author's technic for osteotomy has been described.

2. Osteotomy seems to be the best procedure for all old hip fractures. It is safe and simple to perform and no gadgets are needed.

3. There are no contraindications to osteotomy referable to the condition or position of the fragments and there are a minimum of complications.

4. Osteotomy is useful in many other hip conditions such as malum coxae senilis.

5. Osteotomy may partially or completely supplant internal fixation in the treatment of fresh intracapsular fractures of the hip.

Fig. 3. C, subsequent osteotomy with bony union in both fractures.

6. Osteotomy, previously used chiefly on bad risks, deserves a better chance and better

technic in all types of intracapsular hip fractures.

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DISCUSSION OF PAPERS BY DRS. SIRIS AND MULHOLLAND AND DR. ASBURY

John A. Caldwell (Cincinnati, Ohio): This method of immediate fixation of fractures of the femur has very justly been accepted with a great deal of enthusiasm. It has been one of the major improvements, I think, in the handling of broken bones.

It is difficult to discuss Dr. Siris's cases here but simply to call attention to some of the high points. It is impossible to disagree with most of the things he has emphasized. Failure of union in these pinned hips generally falls into one of three classes: (1) failure of reduction, (2) failure of fixation and (3) an indeterminable factor which is generally spoken of as impairment of the blood supply, in which we cannot really fix the reason.

Dr. Siris mentioned one thing to which I would like to take exception that is, he emphasized in several cases the age of the patient as the factor in failure of the union or in producing union. So far as I am aware, if there is such a factor I do not know what it is. I have probably seen more failures of union in young persons, particularly in children, than I have in the aged. That, of course, has to be analyzed a little more deeply. There are so many more cases of old patients than there are of young ones that a failure of one or two cases makes a big difference in the percentage.

In failure of reduction, probably the most important factor I know of is a good, understanding x-ray service. I have had more failures in those cases in which I have not been able to get that service than for any other one factor.

With the failure of fixation, the one feature in which I personally am interested is the type of fracture in which the head is broken off very high up on the neck that is, the proximal fragment is short. In those cases, they are very difficult to reduce. The fixation is difficult because you do not have much area of bone in which your pin can catch.

Another technical feature is that if you are fixing with a Smith Petersen nail, driving that in may cause the rotation of the proximal fragment so as to displace a good reduction. I have met that pretty generally now in those cases by discarding the Smith Petersen nail and using only the Austin Moore pin. These can be put in place simply by spinning them in and it is not necessary to use a hammer to place them.

I believe that Dr. Siris has given us a splendid résumé of these cases and what is particularly refreshing is the candor with which he refers to his mishaps and his failures.

Kellogg Speed (Chicago, Ill.): I have enjoyed these two papers very much. They open up a very large field of pathology, mechanism and treatment.

I am very gratified also that the fracture oration I had the temerity to give some years ago in Boston, right on Smith Petersen's own home grounds and right at the time of the rising popularity of the fixation by his nail, has borne these results. That oration was purely provocative and the results as coming out in these papers are evidence of the fact that the fracture was not solved then and apparently is not completely so at this time.

Dr. Asbury leaves little approach for discussion, if you have read all his paper. Using his second point, the proper direction of osteotomy must not only insure the possibility of the desired angle of abduction of the shaft of the femur, but must assure a continued apposition of cut-through bone surfaces after the shaft fragment is shoved inward beneath the head. A very oblique angle of osteotomy may permit sufficient abduction of that leg but will not sustain continued later apposition of bone. I prefer high osteotomy at the level he describes, with such angle of displacement that the osteotomy plane will be about 200 degrees with the pelvic wall. Preservation of a periosteal bridge between trochanter and shaft may help to insure certain bony union but, after all, most of the osteogenetic effort, as in intertrochanteric fracture, comes from the large surface of cancellous bone excellently supplied with blood, which is exposed by the cut and yet held in close enough contact to promote bony union, as after fracture.

Bone chips may enhance this union. To obtain them requires greater exposure and more local complicated cutting of bone, which may invite infection and spoil simplicity of technic. I have

not found them necessary in this highly osteogenetic area.

The axes of the main bone trabeculae in the head, neck and shaft fragments must be brought into line and held there in a weight-sustaining position until bony union follows, by whatever means the surgeon elects. Certainly, some immobilization in this chosen position is indicated to avoid the adverse action of muscle pull on the trochanter and shaft fragment.

The failures of osteotomy I have seen depended upon these three factors: too great obliquity of the osteotomy, insufficient medial displacement of the shaft under the head, and too little provision for any immobilization or maintenance of post-operative position. Dr. Asbury is quite right in advising that this method is not a successful cure-all, simply by the twist of the wrist and a chisel. It must be well planned and anatomically executed in each instance.

Charles S. Venable (San Antonio Texas): I am going to discuss this from a little different angle, because the first eight of the various causes of non-union include mal-position and mal-use of mechanical devices or insufficient approach, and I want to take this from another standpoint.

First, let us assume that we have had a proper reduction and a proper application of the internal fixation apparatus, whatever it may be. We know that there is a certain percentage—how much, I cannot quote—of non-unions in those fractures of the neck of the femur which have been properly reduced and which have had proper internal fixation as far as we know how or what. As another cause besides the eight mechanical causes described in the paper, I want to take up the serious phase of insufficient blood supply in the neck of the femur as one of the major causes of non-unions of fractures of the neck of the femur.

We know that the large percentage of non-unions of the tibia, of the lower end particularly, is a question of blood supply, and I think that is a factor. I think all bone, in all fractures, depends upon proper blood supply for union.

We have found associated with necrosis, which Dr. Stuck and I reported some few years ago, that the transposition of muscle into the neck of the femur near its trochanteric base, through a hole about a centimeter in diameter and about a centimeter in depth, carries blood supply and permits ingress and egress of the blood supply into the neck of the femur and on up into the head. For some four or five years now, we have had a most astonishing result of rehabilitation from the moth-eaten appearance of the neck of the femur after necrosis, in which these people are pain-free and have a regeneration of their cartilage and lose all of that necrotic appearance with which you are so familiar.

For that reason, we have done this in some ten or twelve cases, of delayed unions—not in the non-union class, of complete non-union in which there is a fibrosis between the ends even if they were properly set, because you cannot expect blood supply to jump across a gap—but in those cases of delayed union in which you may recognize, when you get into the tenth, twelfth or fourteenth week in older people, that there is no evidence of union. I do not speak of callus because you do not see callus in the neck of the femur, but at that period by a transposition of muscle permitting a greater blood supply into the neck, we have had the most astonishing results in cases of a progressive union, going on to union by virtue of that very simple procedure of the transposition of a segment of muscle inserted and fixed into the femoral neck distal (lateral) to the fracture, which is very easily done and in which there is no mortality and no morbidity to amount to anything.

James J. Callahan (Chicago, Ill.): There are just two points that I wish to discuss.

First, both essayists' pictures revealed that the lesser trochanter and the inferior border of the acetabulum were in contact and formed an articulation. I believe that most of our reconstruction operations are a failure because we do not remove the lesser trochanter. I think that if one will make it more or less axiomatic, that when the greater trochanter is removed the lesser trochanter should also be removed, reconstruction operations will be more successful. This procedure will eliminate the possibility of an articulation of the lesser trochanter on the inferior border of the acetabulum.

Second, where the head is dead or where it is fixed in the acetabulum, as in one of the cases shown, I think it is much better to take out the head and do a reconstruction, because there are two adverse conditions to contend with, namely, the dead head and the possibility of a non-union in the subtrochanteric osteotomy.

Irwin E. Siris [closing]: I wish to thank the discussers.

MANAGEMENT OF INJURIES TO LARGE BLOOD VESSELS IN WOUNDS OF VIOLENCE*

LOUIS G. HERRMANN, M.D.

Cincinnati, Ohio

THE immediate seriousness of wounds of violence depends to a great degree upon the extent and kind of injury to the underlying blood vessels. Methods of controlling hemorrhage from wounds of large blood vessels have excited great interest among surgeons from the very earliest times, not only because excessive loss of blood is always the most serious immediate consequence of such an injury but also because an ample supply of arterial blood to the parts beyond the point of injury must be maintained or serious complications are certain to follow. Since the end-results of the emergency management of vascular injuries in battle casualties of World War II have been so discouraging, a review of the often neglected fundamental principles which govern arterial surgery is particularly fitting at this time.

Operative procedures which are directed toward the reestablishment of the continuity of large blood vessels must be done soon after the initial injury if physiologic restoration of the circulation is to be accomplished. The muscles of an extremity may undergo ischemic necrosis in six to ten hours if the extremity is deprived of an adequate arterial circulation.

In most wounds of violence which affect the extremities, there is also considerable damage to the surrounding tissues, especially the nerves and frequently the bones. The accumulation of blood beneath the deep fascia of such an extremity may further occlude by compression all available collateral arterial pathways.

Often there is associated with these injuries severe shock resulting from diminution in the blood volume with a precipitous fall of blood pressure. When injuries are very extensive, the primary objective of therapy should be to get the patient in the best possible general condition since any premature attempt to repair the vascular damage or to save the limb might easily result in the death of the patient.

EMERGENCY TREATMENT OF VASCULAR INJURIES

The immediate treatment of any injury which involves large blood vessels must be directed toward the prevention of excessive loss of blood. The application of a tourniquet above the site of the injury to control bleeding must be discouraged since such a measure deprives the entire extremity of arterial blood. Even after a relatively short period of time, such ischemia may produce irreparable damage to the soft tissues.

When hemorrhage is less severe and there is the possibility of preserving the viability of the limb, the bleeding should be arrested by digital compression followed by compression bandages. The wound can then be packed with gauze and a reasonable amount of pressure can be applied through the bandage until the bleeding is completely stopped. The use of hemostatic agents such as "gelatin sponges" facilitates the control of such bleeding so that proper supportive treatment can be given to the patient before any definitive operation is attempted.

Care must be exercised in the use of hemostats to control bleeding from an injured large artery since permanent damage to the artery will be produced if the hemostat is applied to the normal arterial wall. If the wound in the artery happens to be a simple tangential laceration, the surgeon will then be deprived of the chance simply to reconstruct the artery by sutures and will be forced to rely upon the more complicated and less satisfactory end-to-end anastomosis to reestablish the continuity of the injured artery.

In addition to the direct attack upon the bleeding vessels, there are other valuable methods of diminishing the rate and amount of bleeding. With vertical elevation of the extremities and mild direct pressure in the wound the

* From the Department of Surgery, the College of Medicine, University of Cincinnati, and the Vascular Disease Services of the Cincinnati General Hospital and the Christian R. Holmes Hospital, the University of Cincinnati.

bleeding from almost any peripheral artery can be controlled until preparations can be made for more adequate hemostasis. Vertical elevation alone often suffices to stop the bleeding from a lacerated artery of the forearm, leg or foot.

If the injured artery is small and not readily accessible or if there is a general oozing from many small arteries and veins, we suggest that the wound be packed with gauze or better, "gelatin sponges," until the bleeding stops. The gelatin sponges can be left in place indefinitely and allowed to heal into the wound but gauze sponges must be removed within two or three days. If the bleeding persists and the patient's condition permits, surgical operation for definitive treatment of the injured artery should be undertaken.

The proper use of transfusions of whole blood and plasma in adequate amounts is essential to successful vascular surgery. We consider it absolutely necessary to restore the volume of blood to approximately the normal level and to maintain adequate fluid and protein replacement to overcome the shock and the peripheral ischemia which result from loss of large quantities of oxygen-carrying red blood cells.

A complete set of sterile instruments and materials necessary to control the bleeding in patients with injuries to large blood vessels should be kept ready for immediate use in the accident room of the hospital at all times.

In many gunshot injuries of the limbs or neck, external hemorrhage may be slight, or even absent, even when one of the main arteries has been injured. This may be accounted for by the contraction of the artery and the curling of the intima with obstruction of the lumen when the artery is completely severed. Although subsequent thrombosis within the artery may produce occlusion of its lumen, this should not be considered permanent since secondary hemorrhage may occur after several weeks when such a thrombus becomes softened and is detached. Tangential injuries or incomplete severance of large arteries may give rise to profuse hemorrhage because the edges of the injured artery cannot retract and obstruct the lumen. In such patients, a hematoma forms in the soft parts of the extremity and the mounting pressure within it tends to restrict the flow of blood from the opening in the artery. However, if this blood begins to infiltrate into the muscular tissue of the extremity, there will be serious compression of the collateral arterial pathways with a further reduction of arterial blood supply. Reaction to this infiltrating blood causes edema of the muscles and multiple incisions in the deep fascia of the extremity may be necessary to decompress the muscles and prevent extensive gangrene of the distal parts of the affected extremity.

When the bleeding about the artery remains localized, it forms a pulsating hematoma which may eventually develop into a false aneurysm. It is usually wise to allow such a false aneurysm to become well localized, and when sufficient time has elapsed to permit the extravasated blood about it to be absorbed, the subsequent cure of the aneurysm by surgical operation will be greatly facilitated. Usually from two to three months should be allowed to pass before an elective operation on such an arterial aneurysm is undertaken. In some instances, however, secondary hemorrhage, dissecting hematomas or infection may make it obligatory to carry out definitive treatment at an earlier time.

In through-and-through bullet wounds of the extremities, when the external bleeding stops spontaneously and when no evidence of serious compression of the collateral arterial pathways is present, we do not believe that the artery should be exposed by an emergency surgical operation. Early exploration of the wound with its associated difficulties due to the extravasated blood around the site of injury may make the exposure of the injured artery difficult and necessitate its ligation thus endangering the viability of the tissues of the extremity.

If signs of an arterial or arteriovenous aneurysm develop, an elective operation should be performed weeks or months after the injury. Arteriovenous aneurysms may cause early, acute cardiac decompensation and for that reason may require operation without delay. Complicating lesions of nerves or bones should never change this attitude toward immediate operation since the repair of these structures is also more likely to be successful if done as an elective operation.

Much of the surgery upon large arteries, however, may be classified as elective surgery and careful study and preparation of the patient are essential if the surgeon hopes to obtain lasting relief without serious complications from his operations. Successful arterial surgery depends upon adequate exposure of the injured arteries by properly placed incisions of reason-

able length and careful dissection of the tissues with as little bleeding as possible.

PRINCIPLES GOVERNING DEFINITIVE TREATMENT

General Considerations. The successful repair of a wound of any large blood vessel is a difficult task and the surgeon must constantly bear in mind that blood vessels carry a remarkable fluid which normally has a tendency to congeal. The formation of clots of blood within a large blood vessel after it has been repaired by sutures, or at the site of the sutures themselves, usually results in failure to reestablish the functional activity and the continuity of the blood stream through the artery or vein.

Most arteries which require repair are either diseased or damaged by trauma; consequently, the physiologic considerations during operations upon such vessels are vastly different from those which concern the surgeon who plans to suture a major artery of a normal man or some experimental animal.

In addition to the problem of intravascular thrombosis in injured or repaired blood vessels, the surgeon is concerned with the adequacy of the arterial circulation to the parts of the extremity beyond the point of injury to the major artery. The factors which determine the state of the peripheral circulation under all conditions are of concern to all vascular surgeons and we must understand thoroughly the principles which goven the proper exchange of arterial blood in the peripheral parts of the body if our management of vascular injuries is to be successful.

Collateral Arterial Circulation. The advantages of knowing the behavior of the peripheral circulation in an extremity or in the brain after the main nutrient artery has been severely injured should be obvious to every surgeon. It is our duty to ascertain by actual tests what alterations in the efficiency of the peripheral circulation will take place if the major arterial trunk of that extremity is permanently occluded during any surgical operation. This is a point of practical as well as vital importance. If temporary occlusion of the injured vessel causes the extremity to remain cold and cadaveric in color in spite of a satisfactory environmental temperature, it is evident that any surgical operation upon that major artery should be postponed. If, however, postponement of the operation is not possible because of the nature of the arterial injury, the surgeon must resort to every available means of restoring the continuity of the injured artery or of enhancing the collateral arterial circulation.

It is absolutely necessary to determine the patency of the communicating pathways between the vertebral arteries and the carotid arterial circulation before the obliteration of the internal or common carotid artery is undertaken. We have advocated the use of local anesthesia when the large arteries of the neck are to be exposed by operation so that cerebral effects after temporary occlusion can be studied for about fifteen minutes to make certain before these arteries are permanently occluded that the collateral circulation is adequate. Severe or fatal cerebral disturbances which follow the ligation of one common carotid or internal carotid artery are due mainly to anatomic anomalies of the circle of Willis. We have followed the suggestion of Matas[1] and have always applied an aluminum band when the common carotid artery was to be occluded, while the external carotid artery is always obliterated by a ligature. If the patient shows signs of cerebral ischemia within several hours after the operation, the aluminum band can then be removed from the artery with subsequent complete restoration of the function of the artery.

If the collateral arterial circulation is active enough to keep the distal parts of the extremity in proper circulatory balance in spite of the injury to or the occlusion of the main artery, we consider it inadvisable to spend the time and labor necessary to perform a successful repair of the artery, since a single ligature on the proximal and distal ends of a completely severed artery will usually suffice to prevent further extravastion of blood into the muscles or to the outside. This is usually true after injury of the external carotid artery, its branches and those peripheral arteries which are paired such as the radial and ulnar arteries and the anterior and posterior tibial arteries. Suturing of defects in arteries should be carried out only when the collateral arterial circulation is grossly deficient after injury which involves the internal or the common carotid arteries or the large arteries of the trunk or extremities. If the injury to the main artery is at a major bifurcation, all arterial branches must be ligated to prevent retrograde bleeding.

Secondary Vasospasm. In most individuals,

the sudden interruption of flow of blood through a large artery of an extremity is usually attended by marked vasospasm in the entire vascular bed of that extremity, consequently, the degree of arterial insufficiency is usually out of proportion to the local injury of the main artery. This secondary vasospasm must be relieved by reflex means since the local application of heat to such an extremity is fraught with great danger. Locally applied heat increases the local metabolism of the tissues but does not greatly increase the flow of arterial blood to the distal parts of that extremity; consequently, the deficiency of oxygen to the tissues becomes greater and local death of tissues frequently ensues. In such instances, the use of vasodilating drugs such as the oral administration of alcohol, the intravenous administration of papaverine or the intravenous use of tetra-ethyl-ammonium chloride is of great importance.

Leriche[2] has maintained for many years that injury to an artery or the application of a ligature to an artery produces reflex vasoconstriction and we have confirmed his observations that the resection of the injured or damaged portion of the artery will bring about some vasomotor relaxation in the bed of that artery. Since 1934, Leriche has advocated the infiltration of the sympathetic ganglia with novocain as the most direct means of providing widespread vasodilatation in the affected extremity. There is considerable difference of opinion about the necessity or even advisability of sympathetic ganglionectomy or ramisection in patients with acute arterial insufficiency following injuries to major blood vessels. We doubt very much if sympathetic ganglionectomy and the sustaining peripheral vasodilatation which it produces, is the best treatment for this type of arterial insufficiency.

Therapeutic Stimulation of Collateral Circulation. There are several different ways of stimulating the flow of blood through the collateral arterial pathways which should be kept ready for use. The intermittent compression of the artery, as suggested by Rudolph Matas, enhances the collateral arterial circulation but, in our own experience, the use of passive vascular exercises (pavaex therapy) is a quicker and more effective means of causing blood to flow through collateral arterial pathways. The physical means of bringing about a reactive hyperemia by venous compression, by the immersion of the other extremity in warm water, or the production of vasodilatation by novocainization of the regional sympathetic ganglia should also be kept in mind as active means of enhancing the collateral arterial circulation.

We believe that the treatment by properly applied alternation of the environmental pressure in the form of passive vascular exercises will actively develop a collateral arterial circulation and will reduce to a negligible degree the secondary symptoms which follow arterial interruption or excision of arteriovenous aneurysms in the extremities.

OPERATIVE TREATMENT

Occlusion of Large Arteries. Contrary to general belief, there are still many dangers associated with ligation of large blood vessels. Although improvements in our surgical methods have lessened the dangers of secondary hemorrhage, it must be kept in mind whenever large arteries of the trunk or neck are ligated. In 1891, Balance and Edmunds expressed the opinion that the wall of the artery beneath the ligature may remain viable and the intimal surfaces will unite if they are brought together over a sufficiently wide area. Upon the basis of their studies they insisted upon the use of wide ligatures which were tied just tightly enough to approximate the intimal surface of the artery without causing any fracture of the arterial wall. Halsted and Reid found further evidence that the ultimate result of ligation of any large artery was directly dependent upon the rapidity of necrosis of the segment of the vessel included in the ligature as well as on the rapidity of substitution of fibrous tissue for this necrotic segment of the artery. By the use of wide ligatures or bands, therefore, the process of necrosis of the arterial wall will take place slowly and a complete substitution of dense fibrous tissues will ultimately occur.

Suturing of Injured Blood Vessels. Preservation of the continuity of a large artery is not without definite hazards. Even though the arterial repair is successful a false aneurysm may subsequently develop, especially when there is considerable structural change in the wall of the vessel or when there are multiple points of injury to the artery. We have always believed that a badly damaged artery or one which shows extensive degeneration should not be expected to perform its normal physiologic function again. When there is evidence of an active collateral arterial circulation,

it would seem to us to be unwise to run the risks of secondary complication which might follow the reconstruction of such a damaged artery. In elderly people, when there may be considerable arteriosclerosis present, we believe that reconstruction of an artery is contraindicated.

The repair of an arterial injury by suture is, of course, the ideal method of restoring the continuity of a large blood vessel and of preserving the flow of blood through that large vessel to the distal portions of the extremity. During World War I, Leriche pointed out that suturing of blood vessels was extremely difficult and usually impossible in wounds of war but in civilian practice favorable conditions frequently exist and wounds can be freed of gross contamination by débridement and thus converted into clean wounds. In the face of infection, secondary thrombosis of the blood vessels or secondary hemorrhage very frequently occurs. The adequate use of antibiotics and chemotherapeutic agents systemically reduces the incidence of secondary infection of these wounds.

A great deal has been written about the management of arterial injuries during the recent war by Elkin, Freeman and others. Freeman has had considerable experience in the repair of traumatic aneurysms of war with reestablishment of the continuity of the large arteries. Elkins' experience with arteriovenous aneurysms was very large and his methods of treatment were based upon the time tested principles of Halsted and Reid.

In civilian practice, the proper use of the anticoagulants, heparin and dicumarol, is of great value in making possible the prevention of intravascular clotting of the blood during the time the sutured vessel is healing.

The transverse suture of lacerations of the arterial wall has been recommended by Learmonth if the laceration has not involved more than one-third of the arterial circumference. Freeman's experience with transverse suture indicates that such a suture can be used successfully even though more than three-fifths of the vessel wall is lacking.

Transverse closures in the arterial wall may produce distortion of the blood stream. There is usually a loud systolic murmur heard over the part of the vessel which has been sutured. It is only when this murmur has a to-and-fro characteristic that it becomes truly significant. The fact that the transverse closure produces a greater diameter to the artery at the point of suture overcomes the objection that encroachment upon the lumen will cause secondary changes in the part of the artery distal to the point of suture. It is our experience as well as that of Freeman, therefore, that transverse suture of a defect in the arterial wall is much more satisfactory than longitudinal suture or an end-to-end anastomosis.

There are numerous ways of placing the sutures to reduce the possibility of secondary thrombosis. The interrupted mattress sutures (Fig. 1B) cause the intimal surfaces of the blood vessel to be brought together without allowing any suture material to extend inside the vessel. If a continuous suture is preferred, the "in-over-and-out" or reversed Connell suture makes a satisfactory means of approximating the intimal surfaces of the blood vessel. (Fig. 1A.) The two needle "cobbler stitch" is rarely used today. It must be remembered that the lumen of the artery must not be constricted too much by the longitudinal suture line lest the artery distal to the point of constriction undergo changes which will eventually result in the formation of a fusiform aneurysm. This is particularly true of the great vessels of the neck and care must be taken not to encroach too much upon the lumen during the repair of the arterial wall.

Non-suture Method of Arterial Anastomosis. This method dates back to the original observation of Tuffier who used glass and silver tubes to bridge the gap between the ends of a severed artery. The more recent work of Blackmore, Lord, and Stefko has given better means of bridging such gaps in arteries by the non-suture method. They have advocated the use of Vitallium tubes either with or without a lining of vein. When such a tube can be lined with a fairly large vein, the danger of thrombosis within the tube is lessened. Their most recent suggestion of using small collars of Vitallium so designed that a free segment of vein can be transplanted by the non-suture method to bridge a gap in large arteries has proved of value when time and the location of the injury in the artery makes repair by suture inadvisable. (Fig. 2.)

The use of a simple Vitallium, glass or plastic tube to restore temporarily the arterial circulation may be life saving. In one of our patients who had both common carotid arteries severed

by gunshot wounds, the right common carotid circulation was temporarily reestablished by the use of an unlined Vitallium tube. The injury to the left common carotid artery was not disturbed because of the patient's serious general condition and there developed within a few days signs of an arteriovenous communication at that site. The patient lived and subsequently a free graft of saphenous vein using Vitallium cuffs and the non-suture method was used to reestablish the circulation through the right common carotid artery. (Fig. 2.) The Vitallium tube remained patent for only about ten days and eventually became occluded by a firm blood clot; nevertheless, we believe that the temporary reestablishment of the continuity of the carotid artery overcame the acute cerebral ischemia and saved this man's life.

Transplantation of segment of veins can also be done according to the method of Murray in which actual end-to-end suture of the artery and the free graft of vein is done at both ends of the graft. When such patients are properly heparinized, Murray has demonstrated that these grafts remain viable and eventually the segment of vein takes on the histologic characteristics of an artery as the result of increased pressure within its lumen.

There are many different methods of performing end-to-end suture and end-to-side suture of blood vessels. (Fig. 3.) The important point is to be certain that the intimal surfaces are brought together without intervening adventitial tissue and that no suture material remains within the lumen of the sutured blood vessels. (Fig. 4.)

The danger of thrombosis following the suture of an artery is not to be overlooked but with the proper use of the anti-coagulants, heparin and dicumerol, the danger can now be reduced to a minimum.

Reestablishing the continuity of large arteries of the extremities after injury may prevent the secondary circulatory disturbances which so frequently are present after the ligation of one of these important arteries. After simple ligation of an injured artery the collateral circulation may be sufficient to maintain the viability of the peripheral tissues but may be insufficient to permit the muscles to function normally under stress. Intermittent claudication is common after otherwise successful ligation of the large arteries above the knees.

LATE EFFECTS OF VASCULAR INJURIES

After any injury in the vicinity of large blood vessels the surgeon must constantly keep in mind the late complications of progressive arterial *thrombosis*, secondary *hemorrhage* or the development of some form of *aneurysm* at the site of injury.

Thrombosis. Either arterial or venous thrombosis of the ascending type may add greatly to the gravity of the situation. Venous thrombosis may lead to pulmonary embolism; when it is extensive in the smaller veins of the affected extremity, it may cause secondary disintegration of the muscles of that extremity. We believe that autolysis of the anterior tibial or calf muscles occurs more frequently after local venous thrombosis in the muscles than from moderate degrees of arterial insufficiency alone. The extensive thrombosis of the major arteries without adequate collateral arterial circulation will always result in mummification or dry gangrene of the distal parts of the extremity.

Hemorrhage. Late severe hemorrhage may occur if local infection is present. When there is clinical evidence of increasing size of the aneurysm or more pain radiating along the course of the artery with rising fever, one must suspect serious complications. Secondary hemorrhage in this type of aneurysm usually requires immediate surgical exploration of the wound with definite arrest of the bleeding by ligation of the injured artery regardless of the possible effects upon the peripheral tissues. Packing with gauze and the application of compression bandages are of little practical value in such instances for the secondary hemorrhage will almost certainly recur unless the bleeding arteries are occluded by ligature. In the presence of serious infection or bleeding, which cannot be controlled by conservative treatment, the aneurysm must be incised, the arteries above and below the sac ligated and all branches leading from the sac occluded by sutures or ligature. Such operations can be properly performed only when a pneumatic tourniquet is applied above the site of injury.

Arterial Aneurysms. The presence of an aneurysm entails various dangers. The form of an arterial aneurysm depends on whether a segment of arterial wall gives way or whether some small spot weakens. The diffuse weakening of the wall gives rise to the *fusiform aneurysm* while a weakening of one spot in an artery forms a *saccular aneurysm*. Long-standing sac-

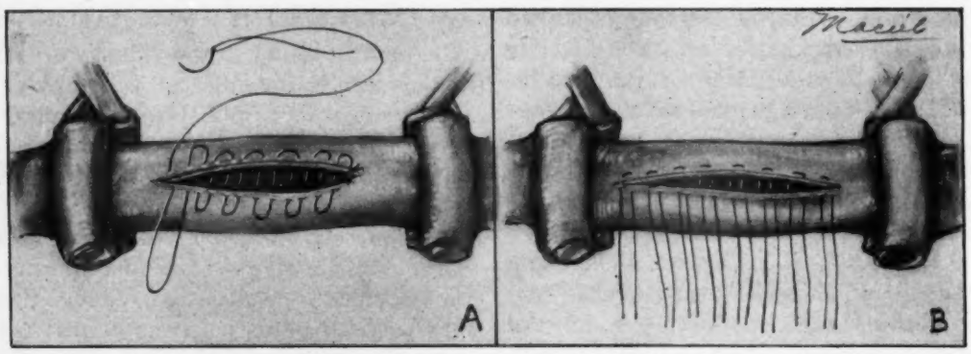

FIG. 1. Methods of suturing large blood vessels. A, continuous "in-over-and-out" suture or reversed Connell suture. B, interrupted mattress sutures which cause an eversion of the edges of the vessel with firm approximation of the intimal lining of the vessel.

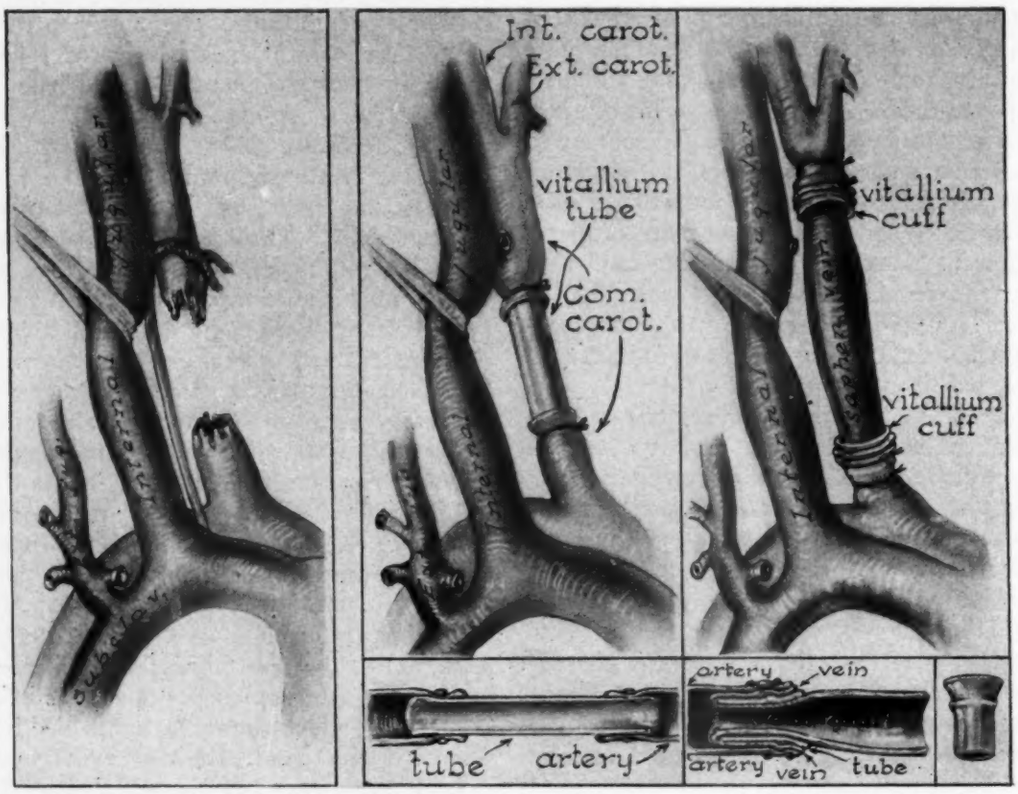

FIG. 2. Destruction of part of the right common carotid artery by a bullet. Temporary reestablishment of cerebral circulation by using an unlined Vitallium tube (emergency measure). Final reconstruction of right common carotid artery by the non-suture method of transplanting a segment of saphenous vein to bridge the gap between the ends of the artery.

cular aneurysms may stretch the entire artery so much that the position of the artery in relation to the aneurysm is eventually lost. The fusiform aneurysm may rupture at one place and assume the physical appearance of a saccular aneurysm. Such physical alterations of shape must be kept in mind by the surgeon who plans the operative procedure for the cure of an arterial aneurysm. True fusiform aneurysms can rarely be treated successfully by plastic operations which are designed to restore the lumen of the artery. Saccular aneurysms, on the other hand, can often be cured by one of the ingenious operations devised by Rudolph Matas and which he designated by the name of restorative or reconstructive aneurysmorrhaphy. Cures may sometimes be effected by complete excision with restoration of the lumen

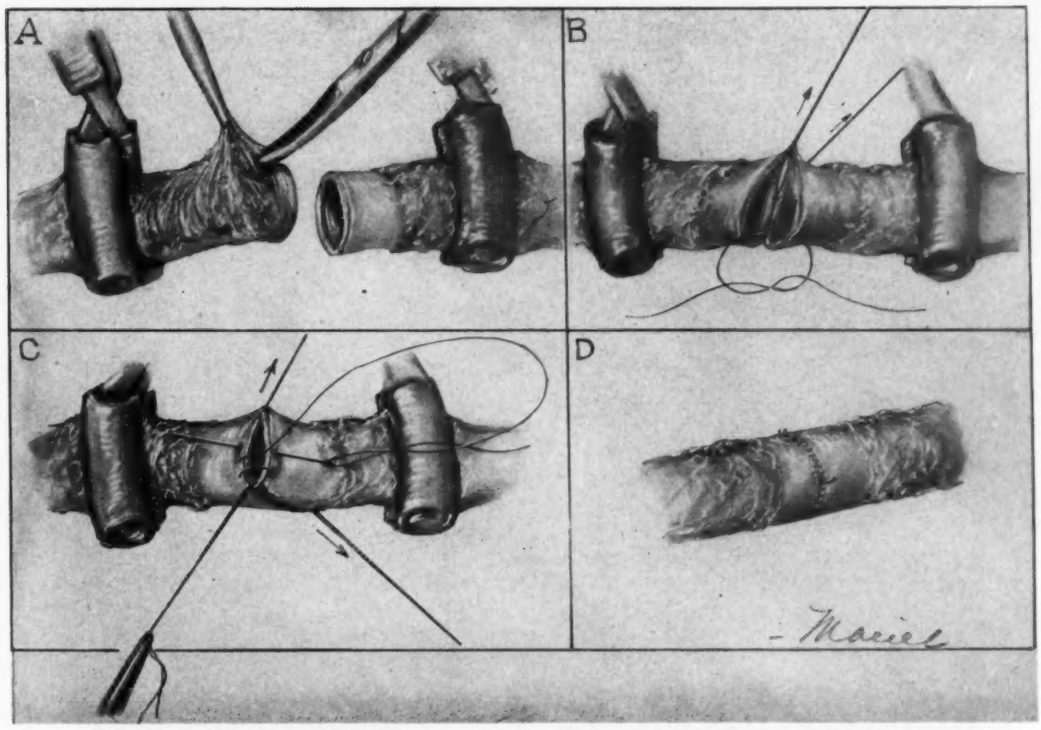

Fig. 3. End-to-end anastomosis of blood vessels by sutures according to the method of Carrel. Note the removal of the adventitia of the artery in the vicinity of the suture line.

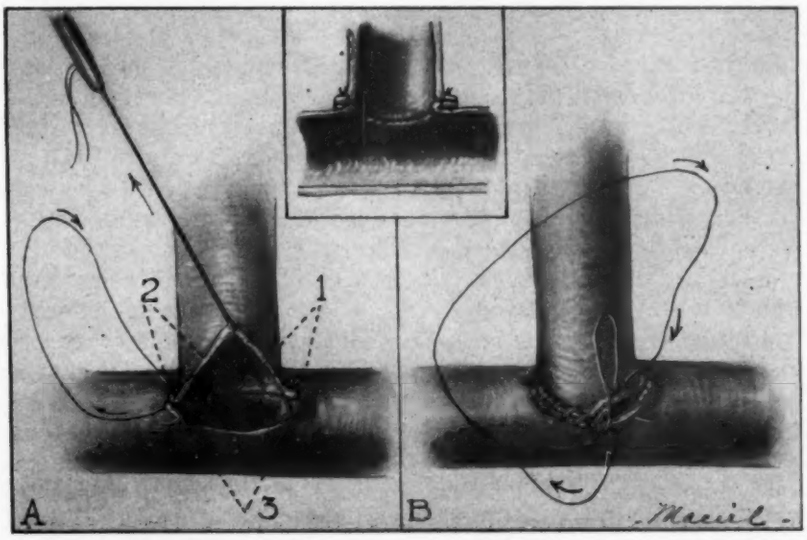

Fig. 4. Method of end-to-side anastomosis of blood vessels by sutures. This is a triangular method using a reversed Connell or "in-over-and-out" type of suture. Note how the intimal surface is approximated without having the suture material extend into the lumen of the blood vessel. Fine silk on atraumatic curved needles is used for all blood vessel anastomoses and repair.

either directly by sutures or by transplanting a segment of vein to bridge the defect.

Dissecting aneurysms may cause pressure upon nerves and give rise to pain or motor paralysis. Aneurysms may even erode bony structure and then give rise to fatal hemorrhage into large body cavities. (Fig. 5.)

Operative Procedures. Operations for the cure of aneurysms must be carried out before extensive erosion of important structures takes

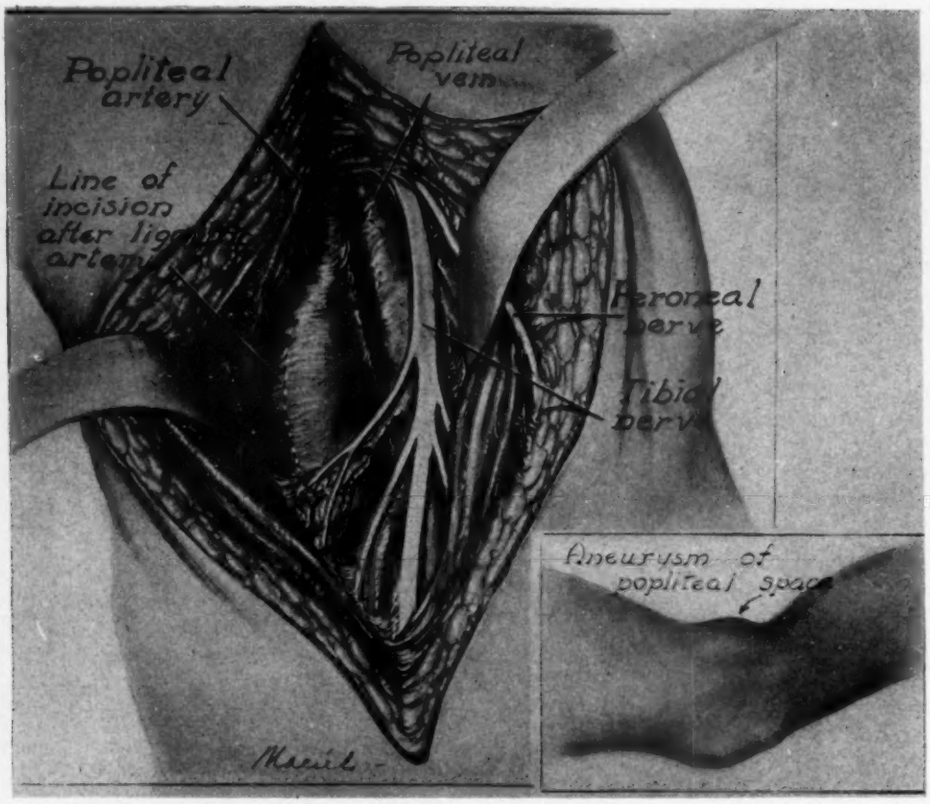

FIG. 5. Traumatic aneurysm of the popliteal artery.

place. If immediate operation is necessary because of bleeding, the artery can be occluded proximal to the aneurysm by means of a metallic band. Should the extremity then become dangerously ischemic, the band can be removed within twelve or twenty-four hours without producing permanent damage to the artery. If gradual occlusion of the artery cannot be tolerated by the patient, some restorative operation should be performed.

Obliterative Endo-aneurysmorrhaphy (Matas Operation). This operation is applicable to ordinary fusiform aneurysms. No attempt is made to reconstruct the parent artery and the arterial orifices are simply obliterated by sutures. By placing the sutures from within the aneurysmal sac it becomes possible to cut the sac off from the circulation without disturbing the adjacent collateral branches and without interfering with the nutrition of the wall of the aneurysmal sac.

Extrasaccular Ligation without Arterioplasty. We have usually used a modification of Antyllus' method of extrasaccular ligation of incoming and outgoing arteries in the treatment of aneurysms in the popliteal space. We have performed an incision of the sac with evacuation of the clots and we have not observed any instance of secondary hemorrhage. The ligation of the artery far above the aneurysm, as advocated by Holman, may be a life-saving procedure when severe hemorrhage takes place; but we believe it increases the danger of gangrene of the extremity and does not cure the aneurysm.

Our modification of the Antyllus operation is indicated in certain types of fusiform aneurysms in which the wall of the proximal artery adjacent to the aneurysm is greatly thinned or is partially damaged. The objection that the extrasaccular ligation of the incoming and outgoing arteries might interfere with the collateral arterial branches is a just one; but if the condition of the artery near the aneurysm is not good, we believe that a much more secure obliteration can be obtained by applying a piece of cotton tape around the artery just outside the aneurysmal sac. (Fig. 6.) After this is done, the aneurysmal sac is opened, the clots removed and any arterial bleeding within the sac is controlled by the application of intrasaccular sutures as described by Matas.

Restorative Endo-aneurysmorrhaphy with Ar-

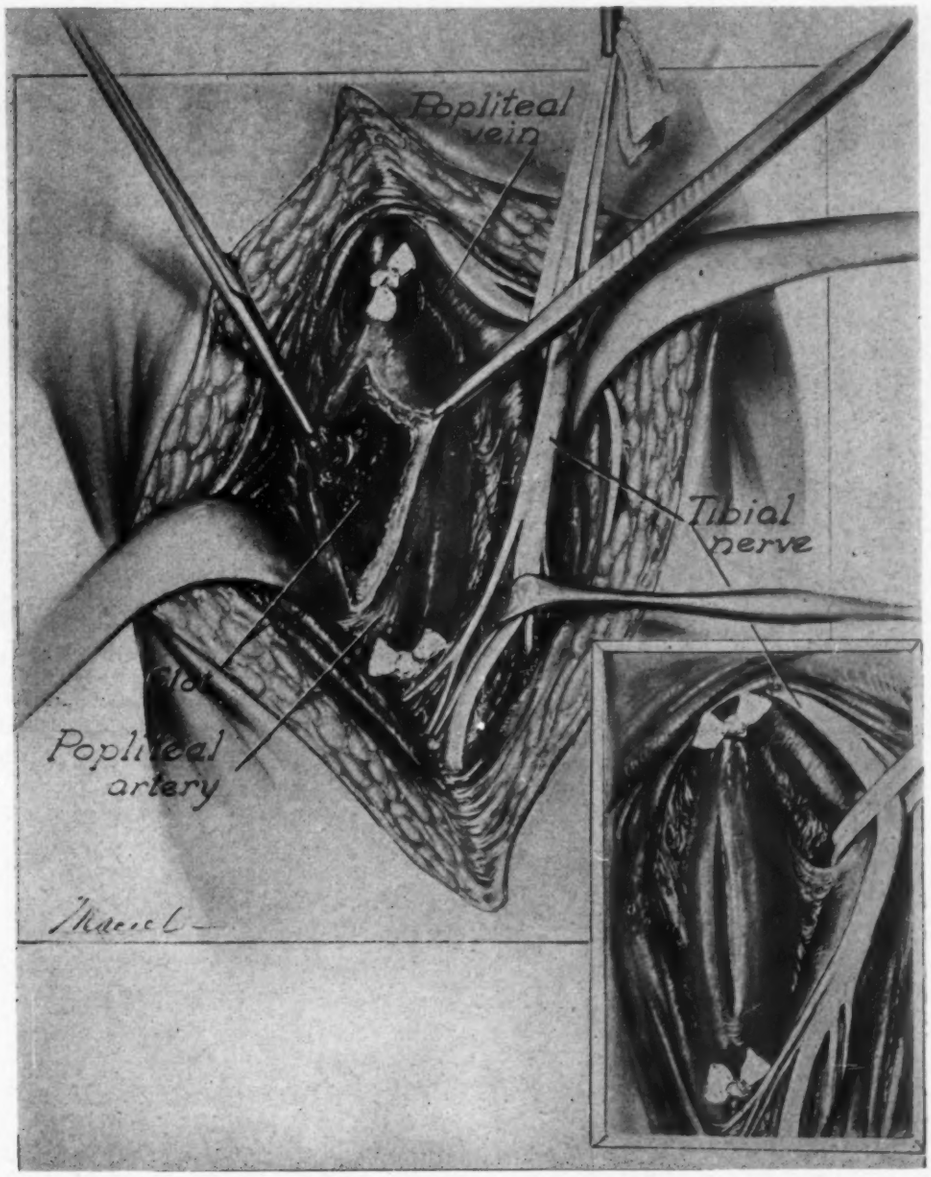

Fig. 6. Extrasaccular ligation of the incoming and outgoing arteries with incision of the sac and evacuation of the blood clots.

terioplasty (*Matas*). In those saccular aneurysms which result from partial injury of the arterial wall and which are the end result of pulsating hematomas, there is usually one orifice of communication with the artery. (Fig. 7.) Matas demonstrated that by opening the aneurysmal sac it was possible to repair the injury to the artery and thus restore its continuity. Such an operation, of course, must be done with the aid of a pneumatic tourniquet applied above the site of injury to the artery. This procedure is particularly applicable in the treatment of saccular aneurysms which develop after injury to the large blood vessels by gunshot wounds, stab wounds, or penetrating wounds in which the wall of the artery is otherwise healthy and can be sutured satisfactorily.

Arteriovenous Aneurysms. The majority of arteriovenous aneurysms are the result of penetrating wounds which injure the artery and vein. During World War I it became apparent that arteriovenous fistulas between large arteries and veins frequently caused progressive damage of the heart. Reid made this observation numerous times and demonstrated that marked hypertrophy and dilatation of the

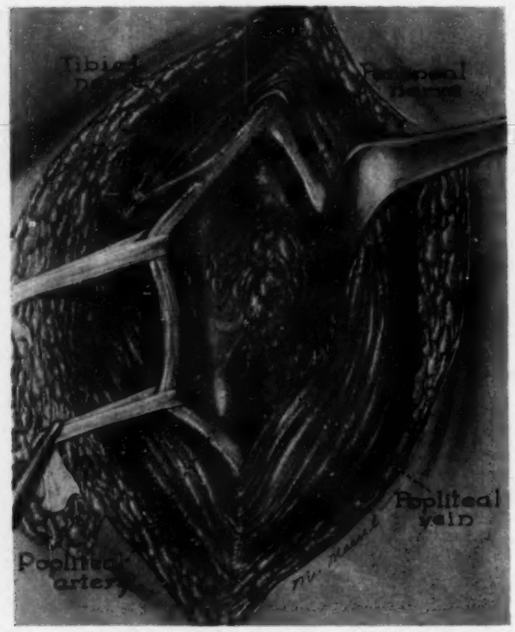

Fig. 7. Arteriovenous fistula between the popliteal vessels. Note the changes in the walls of the vessels at the site of the fistula.

heart resulted from large fistulas between the vessels of the neck, thigh or trunk. In several cases acute cardiac decompensation resulted

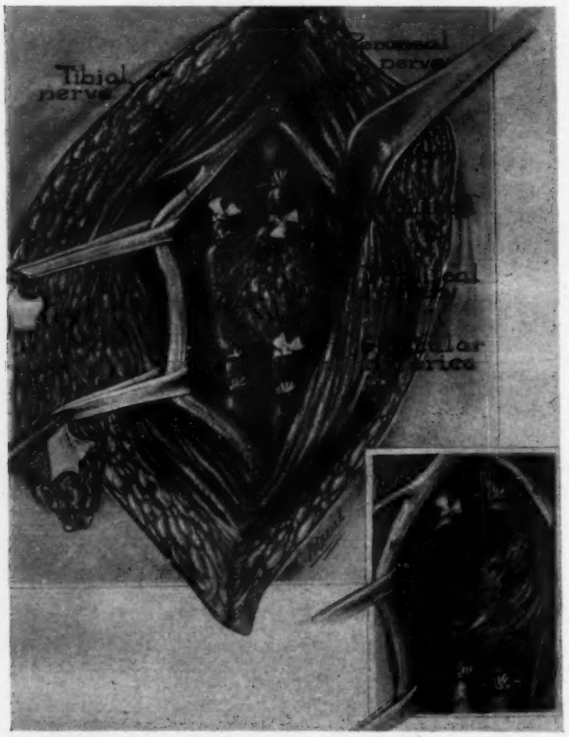

Fig. 8. Quadruple ligation of the vessels involved in the arteriovenous aneurysm with complete excision of the portion bearing the fistula.

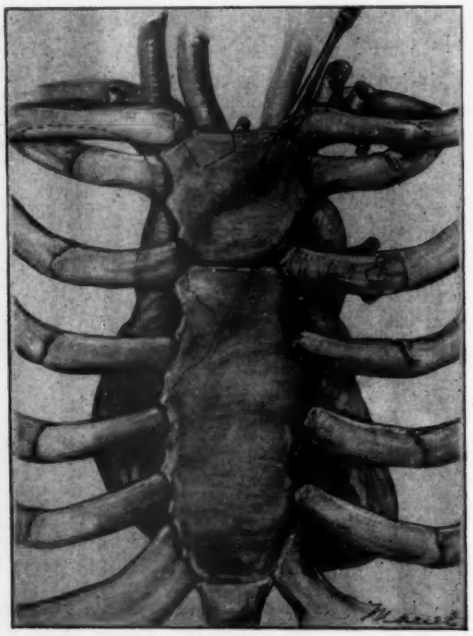

Fig. 9. Drawing showing the course of the knife blade which caused the arteriovenous fistula between the left innominate vein and the aorta at the base of the right innominate artery and the right common carotid artery.

early in the course of the development of the aneurysm. It must, therefore, be borne in mind that it may be necessary to subject the patient to operation much earlier than ordinarily would be the case because of this serious complication. Reports in the literature show that the serious cardiac disturbances or decompensation may come as early as the fifth day after the injury. As a temporary means of relief to the embarrassed heart, Tixier and Arnulf suggested that the vein be ligated some distance proximal to the fistula; and after the cardiac decompensation has been overcome, the curative operation can follow as an elective procedure. The benefits of proximal ligations of the vein in large aneurysms has been observed by Stone, Holman and Matas and the procedure should be kept in mind as a life-saving procedure in those patients showing early signs of cardiac failure.

It is well established that the arteriovenous fistulas act as a profound stimulant to the development of a collateral arterial circulation; for that reason most of the surgeons who deal with these conditions have advocated a delay of several weeks to several months before a curative operation is attempted. In our clinic it has been the practice to delay operation for

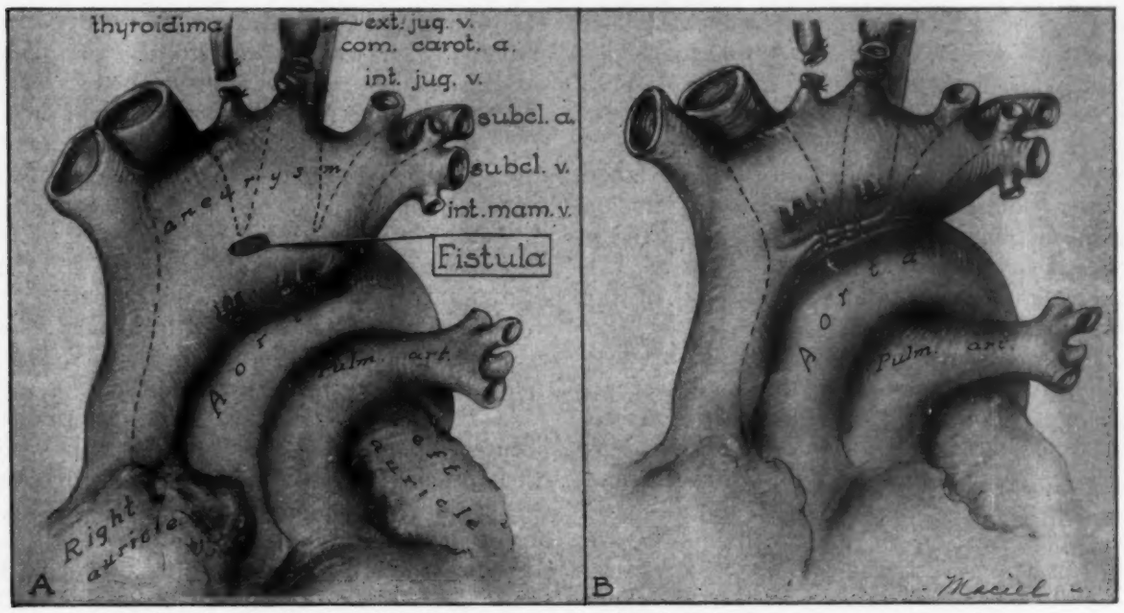

Fig. 10. Drawing showing the site of the arteriovenous fistula after the structures were exposed at operation. The drawing on the right shows the result of the exo-aneurysmorrhaphy with preservation of the left innominate vein and the drainage of the thoracic duct.

approximately six months, especially when the quadruple ligation or excision of the arteriovenous aneurysm is contemplated.

Arterial repair in the treatment of arteriovenous fistulas is not without its hazards and its value may be questioned. Since the occurrence of gangrene after arterial ligation in the treatment of arteriovenous aneurysms is negligible, Freeman raises the question, Why subject the patient to the risk of repair? The answer to that question is relatively simple since in a careful study of the patients in whom ligation of a large injured artery was done, several observers have found varying degrees of chronic

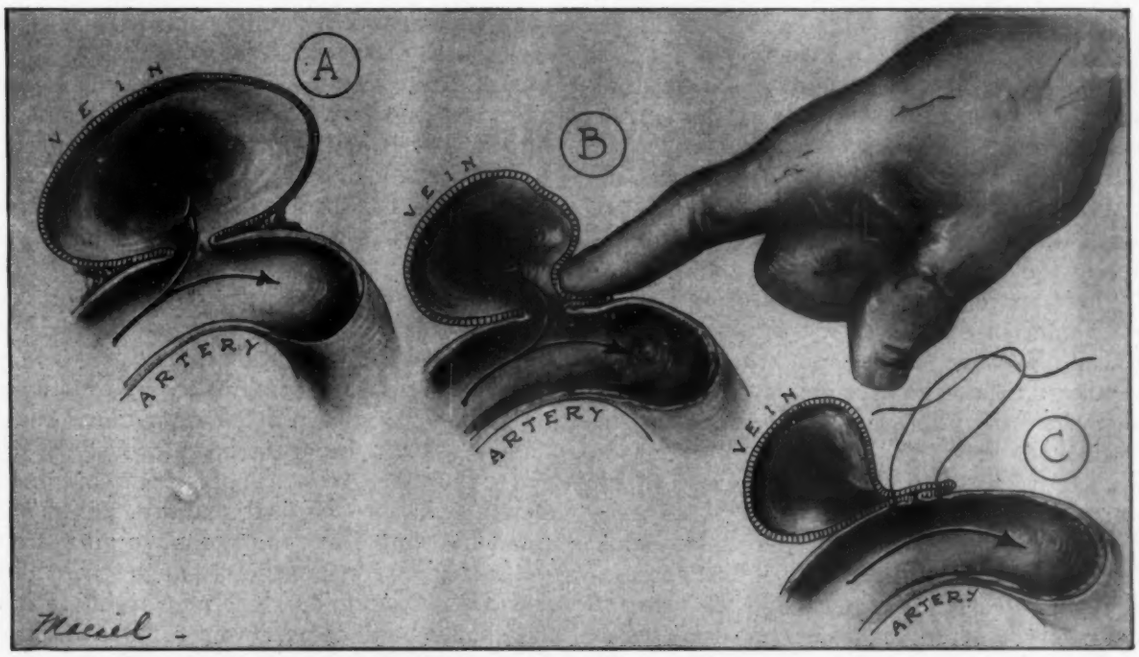

Fig. 11. Drawing showing the method of closing the fistula between the aorta and the left innominate vein and the method of preserving the patency of the left innominate vein by the method of exo-aneurysmorrhaphy.

ischemia of the extremity after an otherwise successful operation. Bigger emphasized this point when he stated that much has been written about the method designed to avoid serious ischemia or gangrene in curing aneurysms and injuries to important large blood vessels, but remarkably little consideration has been given to the sub-acute and chronic ischemia which subsequently develops in such extremities after the ligation of one of the large arteries.

The recent experience of Freeman supports the contention of many of us that early restoration of the continuity of the involved vessels can usually be done satisfactorily. This means a great saving in time of convalescence and hospitalization for the patient. Often after the quadruple ligation of arteriovenous fistulas there is sufficient circulation to care for the ordinary needs of the tissues at rest but there may still be evidence of arterial insufficiency with persistent symptoms of impaired circulation after normal walking. This type of disability is usually completely overlooked. In our own series of quadruple ligations and excisions, as well as in the series reported by Bigger, there are no instances of serious acute arterial insufficiencies, but about 25 per cent of the patients showed signs and symptoms of chronic, mild ischemia of the affected extremity. (Fig. 8.) There is no question but that the restoration of the circulation through damaged arteries, as was emphasized by Matas many years ago, is the ideal method of treatment. Bickham subsequently applied the Matas operation of intravascular repair of the saccular aneurysm to the treatment of arteriovenous fistulas. He was the first to suggest the transvenous closure of the defect in the arterial wall with the preservation of the continuity of the artery and vein.

The transvenous method of closing the arteriovenous fistula has some advantages; but it must always be borne in mind that additional openings in the veins on the opposite side may be present or other weakened areas may be overlooked, hence the aneurysm will not be cured. An objection to arterial repair which cannot be too strongly emphasized is the technical difficulties which such operations entail. Holman has repeatedly cautioned that successful repair of arterial injuries and the cure of aneurysms by transvenous repair depends so much on the ability to control completely all the bleeding. Freeman recently reported successful repair in eighteen out of twenty-three patients with war injuries to the peripheral arteries. Only one patient developed a recurrence of an arterial aneurysm and one developed a recurrence of an arteriovenous fistula after transvenous suture of the opening was performed.

Only by completely isolating the artery from its surrounding tissue can the presence of other communication or other damaged areas in the arterial wall be discovered. Fusiform aneurysms have developed following the closure of arteriovenous fistulas by Reid and by Bigger.

After control of the major arterial supply has been accomplished, we believe that it is absolutely necessary to place a sterile stethoscope over the site of the fistula to make certain that no other arteriovenous communications are present. If the "to-and-fro" bruit continues, the surgeon can be certain that the aneurysm is not cured.

Arteriovenous aneurysms may give rise to large pulsating varices in the subcutaneous tissue of the extremities and thus may bleed profusely or ulcerate and even cause fatal hemorrhage.

POSTOPERATIVE CARE

Patients who have had an injury to large peripheral blood vessels must be watched very carefully with thorough inspection and palpation of the affected extremity at short intervals throughout the first twenty-four or forty-eight hours after the injury. We believe the application of plaster of paris casts should be avoided whenever possible, for the color and temperature of the extremity must be noted regularly; and at the first sign of circulatory insufficiency heroic steps should be taken to overcome this deficiency lest serious consequences follow in its wake.

Vasodilating substances should be given regularly for the first two days and we believe that the oral administration of alcoholic beverages is a very satisfactory way of producing peripheral vasodilatation. Drugs like "spasmalgin" should be given intravenously every two to four hours and the papaverine contained therein will provide satisfactory peripheral vasodilatation. The complete novocainization of the regional sympathetic ganglia will also provide maximum peripheral vasodilatation and should be done every ten to twelve hours during the first forty-eight hours after the injury to obtain maximum clinical benefits.

We do not believe that operations upon the sympathetic nervous system are necessary or advisable as immediate treatment of extremely injured patients since the vasospasm associated with injury to large blood vessels is usually transient and can be overcome by simpler and much safer methods.

We believe it is extremely important to keep the extremity at the proper resting level. An ischemic extremity should be kept at a position about 6 or 8 inches below the level of the heart in order to provide the maximum exchange of blood in that extremity. If the extremity becomes mottled or cyanotic, elevation above the level of the heart for from one to two minutes may be advisable and gentle stroking of the skin from the distal parts of the extremity proximally will frequently free the superficial capillaries of the static blood. Heat must *never* be applied directly to an injured extremity which shows signs of circulatory insufficiency since heat only increases the local metabolism of the tissues without greatly increasing the supply of blood to the particular parts.

The use of heparin and dicumerol has proved to be extremely valuable in patients who have had an injury to a large peripheral blood vessel. Heparin acts quickly and can be given intravenously in doses of 50 mg. every four hours without fear of serious complications. The clotting time should be determined at intervals of about four hours and we have found a clotting time around fifteen minutes represents a satisfactory diminution of the coagulability of the blood. When heparin is given intermittently by the intravenous route every four hours, the clotting time varies a great deal during the four-hour period; and it is sometimes difficult to determine the mean clotting time. We have made a practice of determining the clotting time two hours after the material is injected into the vein.

Dicumerol requires from thirty-six to forty-eight hours to show its maximum effect, so it can be given simultaneously with the heparin and then the heparin injections can be discontinued as soon as the prothrombin time is reduced to a level of about 30 per cent of normal. Both heparin and dicumerol are powerful and dangerous drugs and must be used with caution and understanding. The use of these substances now makes it possible to reconstruct large arteries without having the results nullified by secondary thrombosis. If the coagulability of the blood is reduced by these substances for a period of ten days or two weeks, healing of the injured or repaired artery or vein takes place and no further intervascular blood clots will form at that point.

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DISCUSSION

R. Arnold Griswold (Louisville, Ky.): Dr. Herrmann has brought out beautifully the principles underlying vascular surgery which he and others have preached for so long but which have not been as generally adopted as they should be.

As he said, restoration of the function of the artery should be our principal aim. From a practical standpoint, this is seldom done and not nearly as often as is possible. In a great many cases, of course, it is not possible. Restoration of continuity of an artery in the laboratory is a very beautiful procedure. The wound is usually made with a sharp knife and repair can be accomplished with excellent results. In acute clinical arterial injuries, however, the picture is usually that of a surgeon getting up in the middle of the night, opening up a limb and finding the acute arterial injury. He himself has not mastered the technic of vascular surgery or vascular suture and his operating room is not equipped with the fine suture material, the fine instruments and the other technical things that are necessary for such a procedure, so he ligates the artery.

It has been shown that whenever we interrupt permanently a major vessel supplying an extremity, that extremity is never again normal. It may live, it may look all right, but it never has the endurance or the strength or the resistance of its mate; so I think it behooves us to master the technic and have available at all times the technical equipment necessary for the restoration of contunuity, either by direct union or by a vein graft, with or without the use of Vitallium tubes.

Probably we will not always be able to restore continuity. There is a time factor which does come into it. If the injury of the artery is over six to ten hours old, we are likely to have intervascular clotting, with thrombosis in the arterial tree, which is not reachable by any of our usual methods; so the suture and restoration of the lumen of the artery is not effective. Likewise, in many cases, the amount of artery torn and contused by bullet or shell fragment as distinct from a clean knife wound in the laboratory is so great that quite a length of artery may have to be excised before we can get to healthy enough tissue for an anastomosis. In such a case, only a vein graft would be useful.

The auxiliary methods of aiding circulation which Dr. Herrmann has mentioned are often neglected, particularly block of the sympathetic system, both in acute and old arterial injuries. I prefer when possible to do an operative permanent interruption of the sympathetic rather than too many repeated blocks. If it means a block every day over a period of ten days or two weeks, I would rather do an operation. It is much more satisfactory and certain.

Fasciotomy in cases of excess tension, beneath the deep fascia, has been greatly neglected. The failure to do fasciotomy in cases of high arterial pressure beneath the deep fascia due to an injured artery has resulted not only in loss of many limbs but also in Volkmann's ischemic contracture, both in the upper and lower extremities.

I should like to sound a note of warning about the use of tetraethylammonium chloride in these cases. It is being used improperly. Tetraethylammonium chloride gives you a complete sympathectomy. It does dilate the vessels to the injured extremity but it likewise dilates the vessels all over the body, reduces the general blood pressure and actually decreases the blood flow through the injured extremity. If you are going to sympathectomize for arterial injury, do not do it with tetraethylammonium chloride. Do it with sympathetic block or by operation.

The restorative surgery of aneurysm, both arteriovenous and arterial, is extremely important, because, as Dr. Herrmann brought out and as I said a few minutes ago, whenever we interrupt the main artery supplying any extremity, that never again is a normal limb. In the surgery of the older injuries, the aneurysms and the arteriovenous fistulas particularly, every effort should be made at restorative surgery or the use of a vein transplant in arterial aneurysms or transvenous arterial repairs in the case of arteriovenous fistula.

Lester Breidenbach (New York, N.Y.): Dr. Jeré Lord and I have collected some ten cases in the last year and a half in New York City, in which individuals have had acute injuries to arteries in the extremities resulting in gangrene in most of them, with loss of a part or a great deal of the limb.

In a couple of these cases, as Dr. Herrmann mentioned, there is loss of a limb or certainly a considerable impairment of the function of that limb. There are two ways in which these acute injuries occur: one is in the operating room while the surgeon is operating. One of these cases is one in which a carotid sympathectomy was being done for a sinus syndrome and inadvertently the artery was injured. The surgeon was not well acquainted with the method of repair of the artery and had to ligate it and the result was, of course, a hemiplegia.

Another case was one which was brought to the hospital immediately (and most of these are brought to the hospital immediately because there is severe hemorrhage) in which a knife was accidentally dropped across the upper thigh and the femoral artery was severed.

We have analyzed these cases and found, even in

the operating room under the best of circumstances, that the proper procedure was not carried out because the surgeon was not familiar with arterial suturing. We have, therefore, started an educational committee, as a subcommittee of the Regional Fracture Committee in the City of New York, to try to educate the general surgeon in the methods that are used, which Dr. Herrmann and Dr. Griswold both mentioned, for primary anastomosis of the artery either by vein graft with the aid of Vitallium tube or by primary suture; and most of the time vein graft is necessary because of the elasticity of the artery. Its two ends part over a great distance so a vein graft is necessary. We believe that in this way a great many limbs in the course of a year will be saved if the surgeon has the armamentarium and the courage to go ahead and anastomose the artery. The armamentarium itself is simple and every operating room, we think, should have it. It consists of a few arterial clamps, with rubber-shod clamps (and there are various kinds on the market), No. ooooo or No.oooooo silk, and some Vitallium tubes. With that armamentarium, a good many of these limbs that are lost every year, I think, would be saved.

Louis G. Herrmann (closing): I appreciate very much the remarks of Dr. Griswold and Dr. Breidenbach. I did not have time to cover my subject completely so I am happy that Dr. Griswold called your attention to the danger of using drugs which cause widespread vasodilatation when we are trying to increase the arterial circulation to one extremity. DeBakey has recently emphasized the importance of producing only local vasodilatation in such patients.

I am happy to know that Dr. Breidenbach and his associates in New York are giving this problem serious consideration and are making proper equipment and facilities for the emergency management of vascular injuries available. To most of us this is evidence of surgical progress. We are convinced that many limbs and even many lives could be saved each year if all surgeons were alert to the importance of injuries to large blood vessels in wounds of violence. Prompt diagnosis of the site and kind of injury with as little delay as possible in carrying out definitive treatment and constant postoperative observation with immediate correction of secondary vasospasm have proved to be of utmost importance to the success of vascular surgery. We believe some limbs are sacrificed because the effects of arterial insufficiency are not recognized until extensive and irreparable damage to the muscles has already taken place.

We all must make a determined effort to teach our resident surgeons these important factors in the management of injuries to large blood vessels and then provide them with the facilities which will permit proper care of such injuries at any time of day or night. The progress in this important field of surgery will depend largely upon the success and thoroughness of such an educational campaign.

THE ZERO HOUR IN THE TREATMENT OF TRAUMA

AN ORIGINAL HYPOTHESIS

WILLIAM C. SPEIDEL, M.D.

Seattle, Washington

IT is my firm conviction that there is a physical law of repair in the healing of all wounds. Time is the essence of that law and this is the law: *The healing of a wound is directly proportional to the timeliness of its aseptic coaptation.*

This approach to the healing of wounds, as far as the author knows, is both new and original in its conception. It deviates distinctly from the usual textbook description. It is primarily the straight physical and chemical approach to the healing of wounds.

In order to fit this discussion, let us define a wound as a break in the continuity of tissue. All things being equal, as long as continuity exists function is normal. Immediately ensuing a break there are certain definite changes which take place. These changes are at first physical and mechanical and later chemical and bacterial. It takes time for chemical changes to occur and time is required for the incubation of bacteria, both of which inhibit the perfect healing of a wound. The proper way to eliminate these is to repair the wound while it is still in the mechanical and plastic state. A piece of metal which suffers a complete fracture, if welded while fresh, results in good union. If left to rust or corrode, union is poor. So, in the healing of a wound, it is conditioned upon early approximation. Early, it is a matter of simple mechanical coaptation. The time of election is the period from zero to four to six hours following injury. The physical law of repair then holds good and is: The healing of a wound is directly proportional to the timeliness of its aseptic coaptation. Primary union then occurs and brings early restoration of function.

The secondary period, chemical and bacterial, needs elucidation in order to stress this law further. The chemical and bacterial changes are due to nature's oxidation principle. It is no chance affair that oxygen forms 21 per cent by volume of air, eight-ninths by weight of water, 50 per cent of the earth's crust and one-half of all plant and animal life including human body as well. Oxygen is the disintegrating principle of life, working night and day to dissolve, separate, pull apart and dissipate matter. It causes iron to rust, copper to tarnish, paints to fade and wood to rot. It is the prime factor in the law of conservation of energy. In the human body oxygen is carried in loose combination in the blood stream. The vascular tree is a closed system of oxidation. Oxidation is both upbuilding and tearing down. The best repair of wounds is attained in the pinnacle in between.

For the purpose of illustration I will cite a few instances:

I will first bring to your attention a man with hot solder covering that most important entire pupillary area of the eye. A solid patch $\frac{3}{8}$ inch in diameter deeply imbedded was removed immediately by a painstaking and very competent eye man without any residual opacity.

Some thirty years ago when radical dissection (and I mean radical and complete dissection) was the meticulous procedure for tubercular glands of the neck, after carefully dissecting it out and delicately isolating it, the spinal accessory nerve was cut inadvertently, spelling the much dreaded shoulder drop. Fortunately the neurolema of the nerve was immediately sutured with fine arterial stitch with resultant restoration of function and no shoulder drop occurred after two months' time had elapsed. (We now know that a nerve will grow under such conditions at the rate of two inches in a month.)

Another case was that of a stone laid down in the salivary duct (Wharton's duct) which caused a complete block of the duct with consequent swelling of the gland, illustrating the purely chemical, physical and mechanical nature of the human body.

Another instance is that of a fracture of the right radius $1\frac{1}{2}$ cm. proximal to the distal end with complete posterior displacement of the distal radial fragment. Reduction was made within an hour of the accident. I wish to call attention to the pressure thrust of the sharp

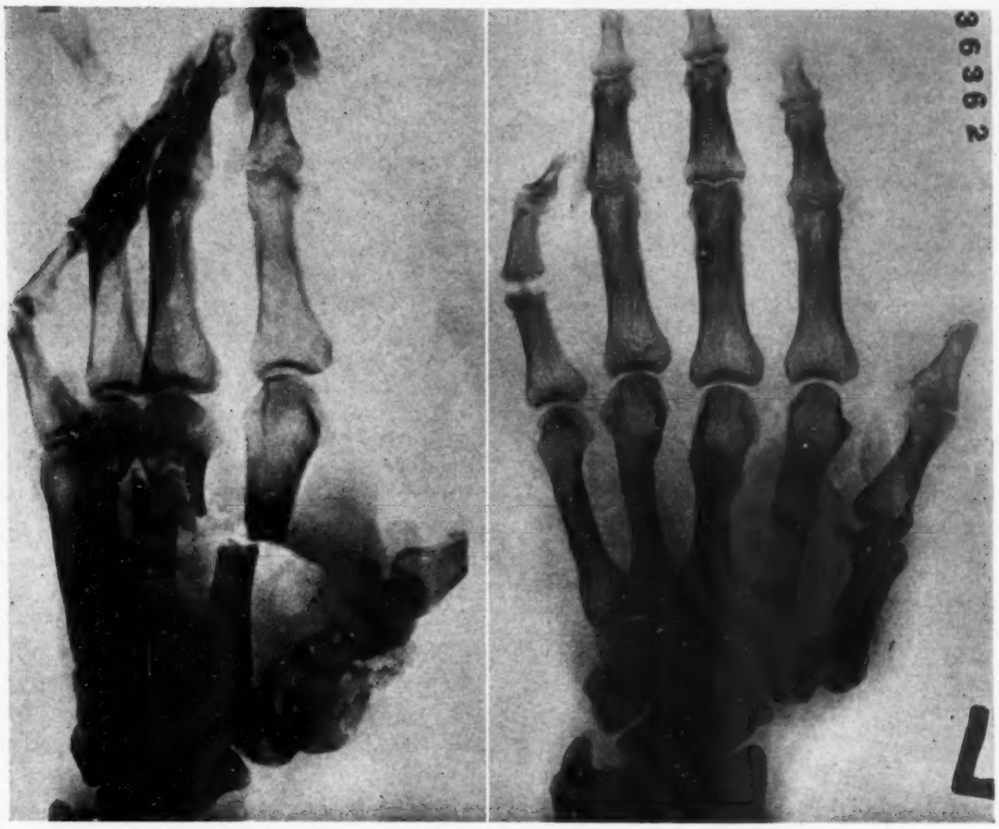

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Fig. 1. Case of injured hand immediately following injury.
Fig. 2. End result of fractured hand shown in Figure 1.

spicules of bone using the homily, sitting down on a chair as contrasted with sitting on a tack. Pressure is the force applied to the unit of area. In addition to that is the matter of decreased surface tension in a fresh wound.

Another case is that of a ruptured gastric ulcer (incidentally, the second such occurrence in the same individual) repaired immediately after perforation.

Still another case is that of an oil tank truck driver who was changing a tire at 11:00 P.M. His left hand was caught between two tires when one of them blew out 65 pounds of air pressure, sending a portion of the tire rim through his hand against the rim of the second tire, a smashing injury involving all of the metacarpal bones of the hand—truly "smashing" as the word connotes—with massive flattening, scattering, and final friction and tearing. An explosive thrust of soft tissue against the firm, unyielding metal produced multiple compound comminuted fractures of all five metacarpal bones and a destructive laceration transversely across both the palmar and dorsal surfaces of the hand with dirt, rubber and débris driven into the soft structures. The bones, unyielding, fractured, and soft tissues, tendons, muscles and nerves were simply brushed aside by this sudden terrific force. (Fig. 1.)

Under pentothal sodium, at 1:00 A.M. I began washing with soap and water—more soap and water—and carried out a thorough cleansing and débridement of the entire wound. Small fragmented particles of bone and all discernible foreign matter were removed. The gross fractures were wired with fine No. 30-gauge wire; bleeding vessels were closed with fine silk. Sulfanilamide and vaseline gauze were spread into the wound and the skin was closed with fine silk and a firm foam rubber dressing applied with plaster of paris cast over all, the final touch being given at 4:45 A.M.

Purposely do I mention the element of "time," for it is brought home here in its full force. This man's hand healed by primary intention with minimal edema and swelling and early restoration to function which brought

him back to his full and heavy duties as an oil tank truck driver at the end of two and one-half months. (Fig. 2.) The successful issue in this case was absolutely due to adherence to proper asepsis, perfect hemostasis, and careful and early coaptation of wound edges *before destructive secondary forces had a chance to take place.* This is a perfect illustration of the law: *The healing of a wound is directly proportional to the timeliness of its aseptic coaptation.*

DISCUSSION

ARTHUR R. METZ (Chicago, Ill.): The author has selected a very appropriate title for his paper, "The Zero Hour in the Treatment of Trauma," and stated as a law the principle that most experienced surgeons practice in the treatment of trauma: "The healing of a wound is directly proportional to the timeliness of its aseptic coaptation."

Experience and time have proved that the sooner a wound is thoroughly cleansed and the anatomic structures repaired and replaced as well as conditions permit, the best wound repair will be obtained.

The "Zero Hour" means "at once," and this principle has to be restated frequently in order to impress upon the students, interns, residents and younger surgeons the importance of giving emergency treatment to all wounds.

The author is to be commended on the selection of the title of his paper and the designating of a law: "The healing of a wound is directly proportional to the timeliness of its aseptic coaptation."

A STUDY OF BONE MATRIX*

THE APPLICATIONS OF ITS REPLACEMENT WITH ARTIFICIAL SUBSTITUTES

STEPHEN S. HUDACK, M.D.,
Associate Professor of Orthopedic Surgery,
College of Physicians and Surgeons,
Columbia University

J. WALLACE BLUNT, M.D.
Annie C. Kane Fellow, New York
Orthopedic Hospital

AND

E. M. K. DARBY, PH.D.
Research Associate in Orthopedic Surgery (Biochemistry)
New York, New York

THE advances in the control of infection, especially in compound fractures, during the period of the past war experience has given us problems in reconstructive surgery for which we were incompletely prepared. Because the quality of surgery was high and the urgency of amputation was postponed many times, we inherited, so to speak, extremely complex mutilations which in the First World War would have been solved by amputation. The quality of surgery reflected the extensive use of blood and blood fractions in combating shock and saving life. Our increased knowledge of the physiology of shock and burns as well as of infection saved many lives which otherwise may have been lost. The advances in knowledge and technic, therefore, saved lives and extremities. It also gave us more complex problems which involved at times, loss of skin, loss of bone, partial destruction of muscle and nerve, but saved the extremity as a whole.

The need to replace bone substance in extremities whose soft parts were relatively intact sometimes exhausted the supply of long bone autogenous grafts. Restitution of the patient depended upon replacement of bone. Parallel problems in the replacement of nerve and skin concern us all, but for this discussion the problem is the replacement of bone. We undertook, therefore, to study the influence of artificial bone matrix substitutes on the tissue of the host site.

The biology of the bone matrix must get more study. Much emphasis heretofore has been placed on the cellular constituents of bone and on the mineral composition. Our knowledge of bone repair has been increased by these studies and by the studies of the enzyme phosphatase. But the basic process of bone healing is still unclear.

It is our purpose here to report some of the preliminary work done on the study of artificial matrices. It is because the process of bone production is incompletely understood and that many applications may be derived from the use of artificial bone matrix that the Office of Naval Research* is supporting these studies. If others will attack the problem of bone production, it is our hope that reconstructive problems contingent upon it will move toward a natural solution.

SUBSTITUTION FOR NATURAL MATRIX

Any attempt at external or internal fixation by plaster, pins or plates is an effort to substitute for the bone matrix which, by trauma or disease, has lost its integrity. Onlay, chip and sliding grafts are operative efforts to guide the reparative matrix to replace the old. All factors which may influence the process of bone repair are of interest, naturally, but before the use of artificial matrices is considered, certain preliminary experiments were done to test again the influence of bone salts.

INFLUENCE OF MINERAL ELEMENTS

The addition of denatured bone powder to the host tissue in the absence of living bone is insufficient to cause bone production. This holds true whether the denatured bone is de-

* United States Navy Department, Office of Naval Research, Washington, D. C., Contract N6-ori-110, Task #2.

* From the Department of Orthopedic Surgery, Fracture Division, College of Physicians and Surgeons, Columbia University, New York, N. Y.

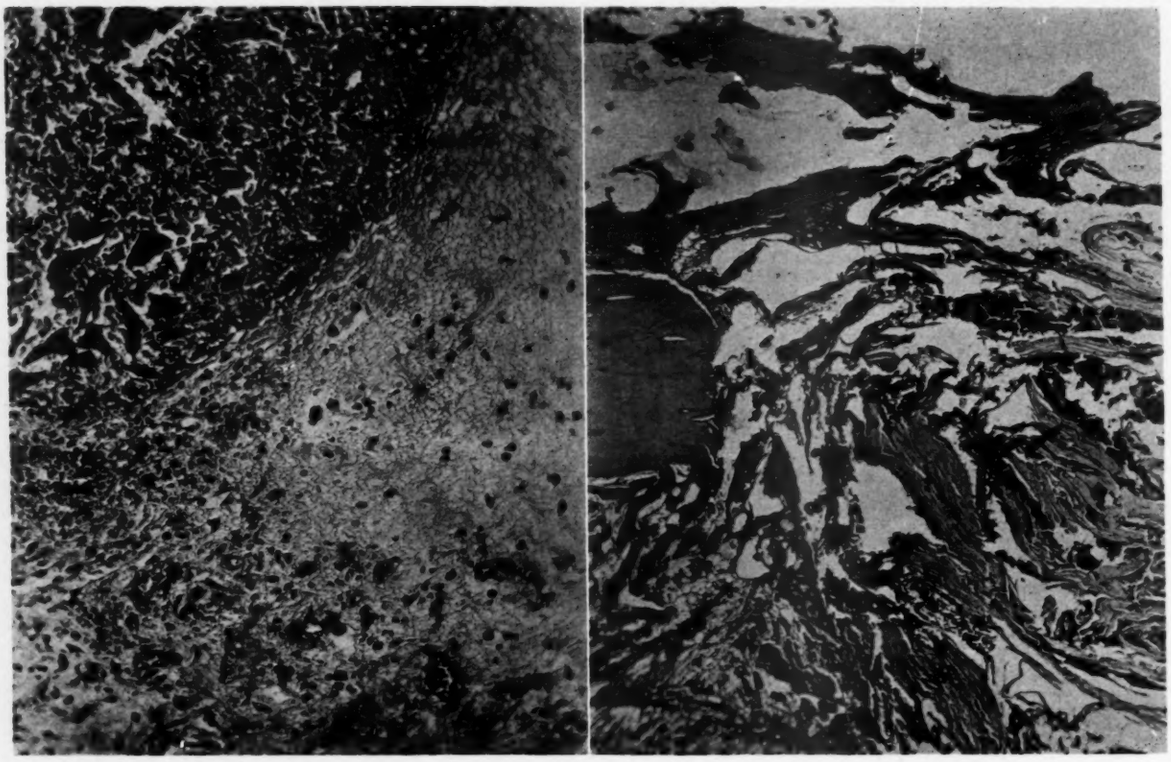

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Fig. 1. Three-day reaction of denatured beef bone in adult rat muscle.
Fig. 2. Autogenous collagen graft in rabbit tibia showing inhibition of bone production.

rived from the animal itself, from the same species or other species.

Heterogenous Bone Salts. In a series of thirty-two rat experiments under standard laboratory nutrition and care, sterile powdered beef bone, previously extracted with 5 per cent sodium carbonate and acetone and washed (final pH 7.3–7.4), was injected or operatively placed into rat muscle separated from bone. In various combinations of circumstance, muscle was used which had been prepared by injury, operatively, or by injection of alcohol —50 per cent and 15 per cent solutions. The animals were sacrificed three days to several weeks after the bone powder had been placed.

The findings in these experiments are as follows: The early acute reaction to three days includes some hemorrhage, a mobilization of neutrophiles and an early organization of a fibrinous and cellular membrane, walling in the donor bone by the host tissue. (Fig. 1.)

As the process became older the neutrophiles began to disappear and cells of the lymphocytic series began to dominate. The cellular débris of the neutrophiles gradually was taken up and fibroblastic infiltration progressed. By four weeks only some of the bone powder débris remained and giant cells were more and more in evidence. At no time in the process or in any individual specimen where the preliminary or operative trauma did not involve bone itself, did bone production take place at the site of reaction about the bone powder.

The preliminary trauma, by injection of 15 per cent or 50 per cent ethyl alcohol or by preliminary operation, did not appear to influence the ultimate nature of the tissue reaction. In other words, the presence of bone salts in muscle with or without previous traumatization, is in itself, insufficient to cause bone production. It is to be borne in mind that this is for denatured beef bone powder in rat muscle.

TRAUMA INVOLVING BONE

In another series of 100 experiments carried out in adult rabbits, the rat experiments were repeated in part. Injury to cortical bone was a variation of operative circumstance added to the experiments. The preliminary series, which did not involve bone injury, again showed no bone production at the site of beef bone powder in rabbit muscle either injured or uninjured. In

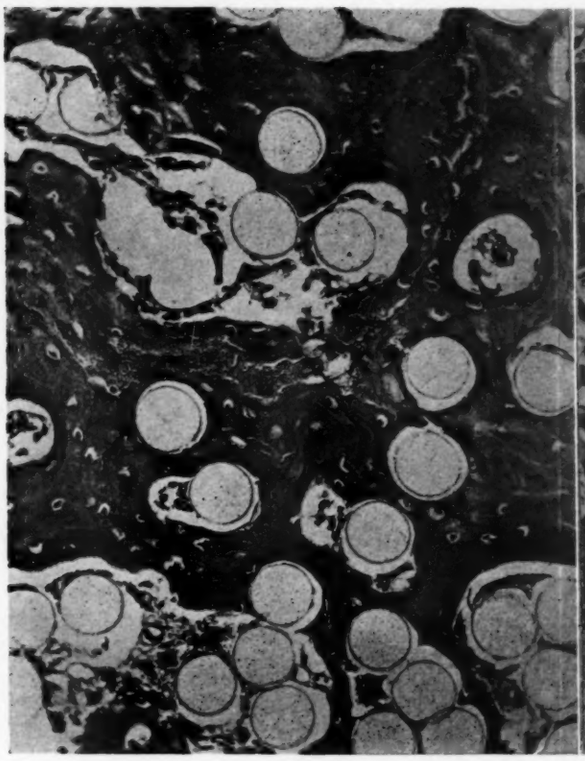

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Fig. 3. Medium high magnification of section of bone matrix incorporating nylon filaments.
Fig. 4. Lucite shreds incorporated in bone matrix.

the series which involved bone injury, matrices were used in connection with bone powder seeding and with the matrices alone for control.

Native rabbit collagen derived from fascia, either processed or used as an unprocessed autogenous graft, appeared to hinder bone production. It resisted revascularization and absorption and appeared as a barrier to bone formation whether it came from tendon, fascia or devitalized periosteum. Its combination with beef bone powder appeared to make no essential difference ultimately. (Fig. 2.)

By contrast, the use of monofilament nylon* appeared to place no barrier to the formation of bone unless certain other factors interfered. If the matrix mass was tightly packed, bone healing was interfered with. Indeed, in some dog experiments to be considered in more detail elsewhere, it was sufficient to promote nonunion. However, the individual fibers appeared quite inert and numerous examples of the filaments completely enclosed in bone are present in sections (Fig. 3.)

* Provided through the courtesy of E. I. Du Pont De Nemours & Company, Inc., Rayon Department, Nylon Division, Wilmington, Delaware.

Polymerized methyl methacrylate was also studied in shreds and filaments and, despite some variability, appeared to be quite inert.

In some experiments, the well dried methacrylate polymer appeared to be as inert as nylon. Certain of the shreds appeared in section to be completely surrounded by bone. In some experiments, "lucite" appeared to be quite irritating to the host site tissues. This peculiarity of behavior is explicable on the basis that drying may not have been complete, the monomer and chloroform solvent persisting. In still other examples, in which the threads had been allowed to stand too long in alcohol for sterilization, there may have been some depolymerization. (Fig. 4.) The use of rabbits in these experiments, employing the tibia or the femur, was not entirely satisfactory. The results were sometimes obscured by secondary fracture and infection.

The study of vitallium as a replacement or substitute for bone matrix has been reported by Venable[1] and except for certain technical defects, appears virtually inert as far as tissue reaction is concerned. Vitallium has been applied successfully many times in its clinical use

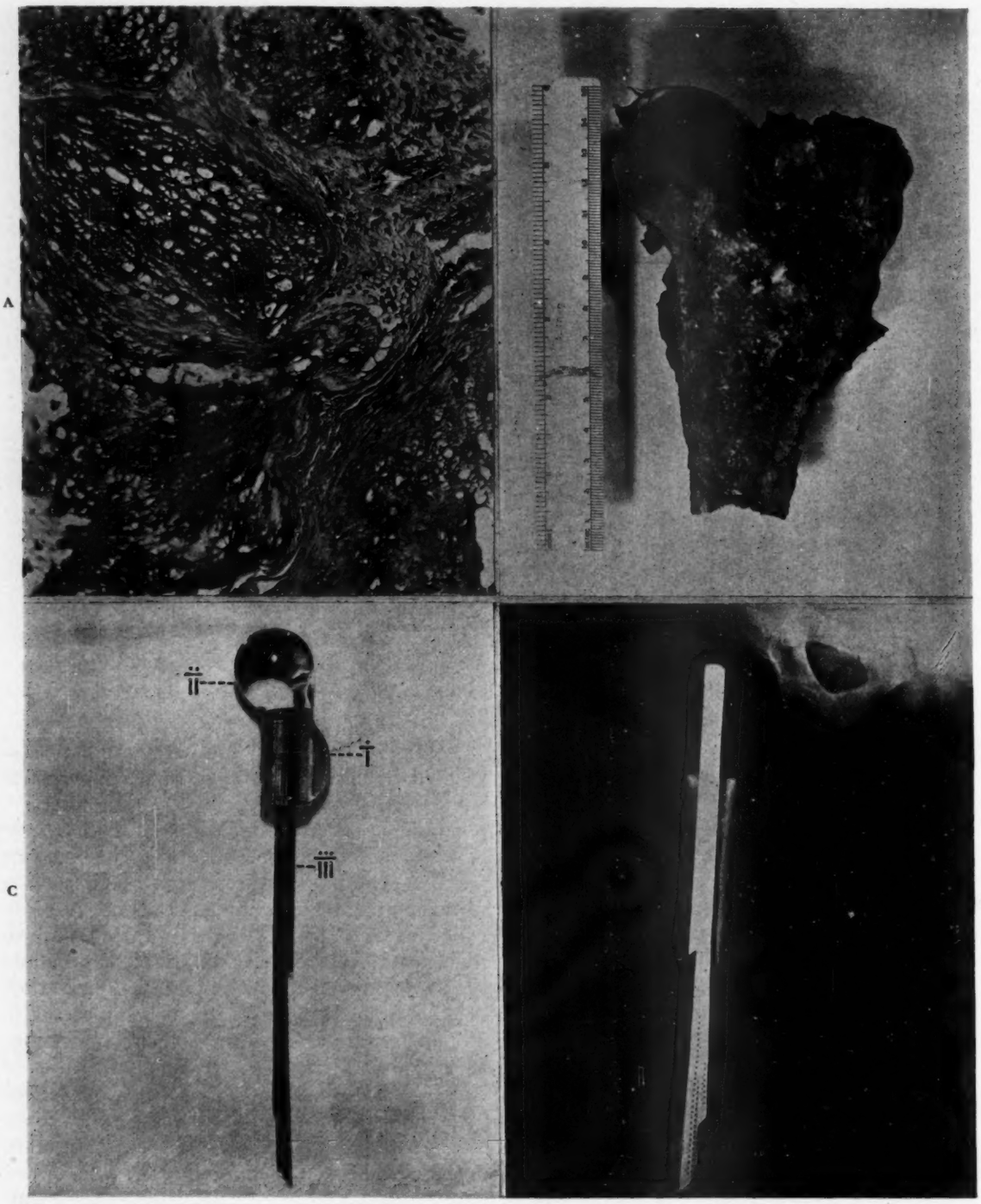

FIG. 5. A, microscopic section of well differentiated chrondrosarcoma. B, longitudinal hemisection of postoperative specimen. C, anteroposterior view of articular replacement element. Note: i, the reattachment flanges; ii, the head element; iii, multiple perforated intramedullary pins. D, postoperative x-ray showing element in place three months after operation when patient was weight-bearing.

for internal fixation of fractures and in cup arthroplasty.

The use of stainless steel chrome nickel alloy has been studied and reported elsewhere.[2,3] Its use more recently for intramedullary fixation of fractures was extensively reported in foreign literature following its introduction for that purpose by Küntscher.[4] Chrome nickel alloy alone and in combination with lucite is being studied at present by the authors, both as a substitute for bone matrix and in articular replacement. This work is not, as yet, ready for publication. One instance of its clinical application may engage your interest, however; it is a case which, as yet, has not a sufficiently long follow-up for a case report and will be cited merely as an application of the work being reported here. (Fig. 5A, B, C and D.)

On January 30, 1947, D.S;* a thirty-eight year old white woman was operated upon and a chondrosarcoma (Fig. 5A) involving the upper femur was excised. A replacement element was substituted for the excised portion. (Fig. 5B.) The articular element was lucite and the multiple intramedullary pins, having multiple perforations (Fig. 5C), were of chrome nickel steel.

The patient was out of plaster and capable of bearing full weight at nine weeks. (Fig. 5D.)

THE MATRIX

The investigation of matrices involves a dual problem. In one, we seek to find or develop a matrix which in a microscopic sense is inert and can become incorporated in the tissues of the host site. It must not inhibit bone formation and must be capable of becoming the physical vehicle and strut work to make possible the development of artificial grafts when the factors regulating bone production are more completely understood. Some work in this direction is reported by Blum[5] using phosphatase and lucite. A subdivision of this first phase of the problem is the development of a physical matrix for reconstructive work which may be utilized in regions of questionable sterility, such as in maxillofacial defects and old infected lesions. To avoid sequestrums, this matrix must be tissue soluble. The work on the tissue soluble matrices is not sufficiently developed to report here. However, gelfoam and fibrin foam and others are under consideration.

* By courtesy of Dr. S. R. Gaston of The Fracture Service Staff, Presbyterian Hospital, New York City.

The second phase of the matrix problem is to find one with physical and biologic qualities which can withstand the strain placed upon it as a substitute for bone but which at the same time, is sufficiently inert to permit the formation of bone around it. This latter application, for example, would be very important in problems of loss of substance in long bones or in excisions of neoplastic and other lesions with necessity of extensive grafting or other replacement.

The first phase of this problem is now being investigated by the authors and some experiments carried out in dogs may be reported in part.

Bridging of Bone Defects. A series of forty-two experiments were set up in dogs in which the nature of repair was studied after the creation of a gap of 1.5 cm. in dog radii. A gap of this size in adult dogs almost invariably goes on to a fibrous union. In control experiments the matrix to be studied was used alone. Under surgical asepsis, the dog radius was exposed in its mid-portion and the 1.5 cm. segment excised. The resulting gap was filled with the matrix and the wound closed surgically in layers. In all the control experiments, nonunion resulted. The nylon and lucite threads when loosely packed did not inhibit the formation of bone. The bone matrix was capable of growing through the matrix gap. In some places, the donor matrix strands were completely surrounded by bone and became incorporated into the host tissue. If the packing of the gap was too dense, the conditions for bone matrix deposition were disturbed and the donor matrix was virtually rejected; in other words, very little bone matrix grew about the donor shreds.

Occasionally, when the lucite matrix was inadequately dried or proved irritating to the host tissue, it was walled off and not even fibrous tissue would invade the donor mass. This happened with nylon, too, if the packing was too tight. The excised portion of the radius was usually saved. It was cleaned of soft tissue and marrow and preserved in 70 per cent alcohol. This section of the radius, and in a few instances rib substance taken out at the first operation, was cut into a fine powder with a rotary file and used for autogenous bone powder. It was processed and denatured with the same technic as the beef bone powder for the rat and rabbit experiments.

There was deposition of bone matrix in the presence of lucite and nylon shreds. The addition of autogenous bone powder to the lucite and nylon filaments did not inhibit bone production nor did it appear to stimulate it. Beef bone powder and dog bone powder, not autogenous, did not influence bone production critically. In two dogs, bone bridged the gap at four months but the result was invalid because, in both, the epiphyses had not closed.

CONCLUSIONS

1. The seeding of rat and rabbit muscle tissue with denatured bone powder is not sufficient to cause bone production. Whether or not the host muscle is injured in preparation appears to make no difference.

2. Collagen as an artificial matrix (denatured fascia or tendon) appears to resist vascularization and absorption, and bone matrix does not grow into or among its strands.

3. Lucite and nylon filaments appear to be inert bone matrix substitutes. They permit the penetration of the reparative bone matrix in and about the donor mass.

4. A clinical application of the use of bone matrix substitute is cited.

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DISCUSSION

Arthur G. Davis (Erie, Pa.): I am not fitted to go into the experimental side of Dr. Hudack's work critically. However, I have this interest, that from the purely clinical side, we are in a state of flux as to what constitutes callus formation. Dr. Hudack is attempting to bridge gaps, and apparently successfully, with inert material.

But, first of all, I must disclaim any first-hand knowledge of the experimental laboratory in the matter of callus formation. There is the necessity for the clinician, however, attempting to reconcile the clinical fact with the laboratory evidence. Dr. Hudack properly predicates his remarks on the fact that the nature of callus formation is unknown. Being thus confronted with an inexplicable phenomenon permits me the privilege of choosing between schools of thought, the one I think the most logical. I prefer, therefore, to limit my discussion to this phase.

The new school, among whom the names of Dr. Clay Ray Murray and Dr. Stephen Hudack are significant, seems to be gaining ground. I find their viewpoint much closer to the clinical fact than that of the "osteoblastic theory," in spite of the ubiquitous but still mysterious osteoblast. Their work has been augmented lately by the addition to our knowledge of molecular structure, x-ray diffraction patterns, crystalline lattices and their self-propagation, the study of matrices simulating fibrin and collagen, the micellar brush heaps, the crystallite and linear theory of protoplasm and the readiness with which undifferentiated protoplasm can rearrange its molecular structure, depending upon the physical and chemical factors composing its immediate environment. All this tends to substantiate the earlier observations of these contributors.

The chronologic order of events in the gross seems to be supported by laboratory evidence, from the time of the injury and tissue death with its accompaniment of acid phase, the interval of clot, granulation tissue, capillary buds and anastomotic circulation between fragments completing the fibrous tissue phase. The temporary acid state, making available a high concentration of utilizable calcium phosphate from local structural bone, the agency of an adequate local circulation in changing from the acid to the alkaline side of the neutral point and its effect on activating phosphatase for subsequent utilization of calcium phosphate, seems altogether comparable to the magic effect of vitamin D in rickets.

The proof in the case of the antirachitic factor in the growth of bone is undeniable. The question of phosphatase or other enzymes liberated by cell death and their agency in initiating calcification in the undifferentiated matrix may be described as plausible and significant rather than as yet proved fact.

At this point, however, the laboratory leaves off abruptly with an amorphous semi-plastic mass of new building material which gradually takes form. This theoretical and fortuitously constructed brush heap then transforms itself by some magic into structural bone. Not only that, it also automatically compensates for transitory architectural redundancy. Where bone projects uselessly into soft parts, it disappears. Where there is not enough functional and structural integrity, more and stronger cortical structure makes its appearance always on the side of the maximum compression strain.

This latter phase seems explicable on the basis of the compression and tension members contained in

living architecture. How common the clinical experience of the transformation induced by converting shear strain into compression strain! One cannot escape from the omnipresence of compression. Shearing, compression and tension cannot be considered apart from the chemical reaction, whether it be in the gross or minute.

Recent evidence tends more and more to accent the importance of compression strain. Such evidence as that afforded by Phemister's work in converting a pseudarthrosis into a solid union by creating new conditions, new stimulation in a nonunion area, plus compression strain—simply allowing the two fragments to metamorphose by compression the fibrous tissue and start a new calcifying process—is altogether similar to the Schenitz osteotomy of the hip. Then we have also the new method of Dr. Eggers. I discussed Dr. Eggers' paper in Chicago, and you may be familiar with his work. He has invented a plate in which the bone fragments are secured only partly to the plate. There is a slot in the plate which allows the two fragments to approximate each other, his theory being that if the normal tension within the living chamber—and I think that we cannot lose sight of that because it is always there as part of the environment under which callus forms—if this rack, in which the two fragments are held, is allowed to slide and is not firmly fixed as it is in the Sherman or Murray type of fixation, the jamming of these two fragments then induces this compression strain. At any rate, Dr. Eggers' cases are working. I am not convinced enough to use it, and I am waiting for more evidence, but when we see something like a hundred cases of Dr. Egger's, I think we may be convinced again of the effect of compression strain.

Pressures induced by normal muscle tension all appear to be consistent with the modern conception of crystalline lattices and collagen matrices as agents to bone formation.

In the end, I want to say that I am very grateful to have had this chance of glimpsing Dr. Hudack's most recent work, and I have found the physicochemical conception much more in line with the clinical work that we do. Without knowing anything first hand about the laboratory but simply noting the experimental facts and modifying the method accordingly, in bone grafting large defects and non-unions the clinical facts seem to agree with the laboratory evidence. I would like to add this testimony to Dr. Hudack's work.

John C. A. Gerster (New York, N.Y.): I would like to ask Dr. Hudack if certain abnormal occurrences of bone would shed any additional light on the research he and his associates are doing? Occasionally, bone is seen in places where it has no business to be, for example, in the scar tissue of certain abdominal wounds. It is known that the autopsies on John B. Murphy and on Theodore Roosevelt showed bone formation in the atheromatous aortic plaques of those two outstanding examples and exponents of the strenuous life.

And lastly it has been known that bone has occurred between the two corpora cavernosa as reported by my father.* The subject was a Frenchman who wore a corset. He was rather adipose, and when sitting on the edge of his chair, the lower edge of the corset impinged on the penis. Whether the constant trauma of this corset was causative we do not know. These are examples of bone occurring where it has no business to be and not near anything except connective tissue and calcium deposit.

Stephen S. Hudack (New York, N.Y.): The frequency with which callus or bone deposit takes place in one site of a repairing fracture and not in another testifies to the fact that the intimate conditions of a very circumscribed nature are capable of controlling the deposition of bone

The importance of Dr. Gerster's comment on the heterotropic bone formation again simply supports the concept that so-called specific osteoblasts are not necessary in the formation of this type of bone. There are no osteoblasts in epigastric scars. Inferentially, one is drawn to the hypothesis that the undifferentiated fibroblast which is present as a response to injury is capable of differentiating so that whatever materials are necessary biologically or physically for the production of bone at that particular site, if there is some factor which the living cell contributes—and I am confident that eventually we will learn that that is so—it does not have to be the so-called specialist osteoblast, but these cells may derive from the primitive cells which are present in response to injury in any region.

Of course, we do not know enough as yet about the concentration of phosphatase and other factors which appear to be necessary in the process of bone formation except that, for instance, in places like the kidney or bladder, in conjunction with fascial grafts and things like that. Bone can be produced where osteoblasts are not present.

I hope that in perhaps another fifty years, I can answer Dr. Gerster's question. Right now, I do not know.

* Gerster, A. G. Formation of bone in the human penis. *Ann. Surg.*, July, 1915.

INJURIES TO THE HIP JOINT*

TRAUMATIC DISLOCATIONS INCURRED CHIEFLY IN JEEP ACCIDENTS IN WORLD WAR II

MARSHALL R. URIST, M.D.

Chicago, Illinois

THIS paper is the first of three communications concerned with the analysis of fifty-eight injuries of the hip joint treated definitively by a single surgeon in World War II. They were observed over a period of eighteen months (1944–1946) in twenty U. S. Army hospitals in the European Theater of Operations which admitted approximately 25,000 battle and non-battle casualties over the same period. Forty of the fifty-eight injuries were incurred in jeep accidents. Both before and after the institution of definitive treatment, the patients, as is inevitable in warfare, were treated by a variety of medical officers ranging from general practitioners briefly trained to handle military surgery to experienced surgeons whose views and practices concerning the management of such injuries varied widely.

The series of cases seems worth reporting on several counts: (1) It includes as many cases of this type of injury as would usually be admitted to a large urban hospital over a period of fifteen years. (2) Even though the absolute numbers are not large, the series provides sufficient clinical material for an evaluation of the current teachings and practice in respect to these injuries. (3) Because so many different medical officers participated in the treatment of these patients, the series is of historic interest and may fairly be considered an over-all picture of the management of injuries of the hip in World War II.

For convenience of analysis the fifty-eight cases have been divided into three groups: dislocations of the hip joint (fifteen cases), fractures of the acetabulum without dislocations (sixteen cases) and fracture-dislocations of the hip joint (twenty-seven cases). The dislocations serve as a control group for the fracture-dislocations. The fractures of the acetabulum serve as a control group for the injuries to the articular surfaces in the same group.

This first communication is an analysis of fifteen cases of dislocation of the hip joint (Table I) sustained chiefly in jeep accidents in France and Germany in both combat and non-combat circumstances in World War II. Follow-up reports have been obtained in as many instances as possible approximately two years after the injuries from letters and roentgenograms submitted by patients and their local physicians or from examinations reported by Army and Veterans Hospitals. The end results of the injuries as determined from these sources are compared with the end results of similar injuries as determined by the examination of patients at the Massachusetts General Hospital at various periods of time after the injury was sustained.

MECHANISM OF INJURY

The exact mechanism of injury in the fourteen posterior and one anterior (obturator) dislocations which make up this series was frequently not possible to determine exactly. Circumstantial evidence, on the basis of the location of contusions, bruises and fractures in the ipsilateral extremity, suggested that all dislocations and certain types of fractures of the hip joint were produced by a forceful blow on the flexed knee or on the sole of the foot, transmitted through the extended knee, either alone or in combination with violent blows against the lower back and the lateral aspect of the hip. (Fig. 1.)

It was the impression of the military surgeons who participated in the management of these cases that severe injuries of the hip, which are so uncommon[9,45] in civilian life, were relatively more common in World War II because of the new types of mechanization and of violence which had been introduced. Other contributing factors were also operative. The excitement and recklessness of men at war can, as always, be invoked to explain a high incidence for all types of severe injuries. Age or, more correctly, youth also played a part. With the exception of a single patient who was fifty-one years of age,

* From The University of Chicago, School of Medicine, Chicago, Ill.

all the patients in this series were between the ages of nineteen and thirty-three, the age group in which the incidence of traumatic dislocations of the hip is always highest.

More specifically, the circumstances of injury explain the nature of the injury. With few highways which permitted and encouraged travel at a high rate of speed were responsible for many of the accidents which occurred in the European Theater of Operations.

All of these considerations, although valid, do not detract from the special fact that the

TABLE 1

DISLOCATIONS OF THE HIP JOINT IN MILITARY PERSONNEL

Case No.	Age	Other Injuries of Ipsilateral Extremity	X-ray	Traction (wk.)	Weight-bearing (mo.)	Two-year Follow-up
1	21	Contusion knee	No fracture	5	4	Mild pains
2	20	.....	Serration, posterior rim	6	Unknown	Mild pains
3	27	Contusion knee; dislocation patella	No fracture	5	3	No follow-up
4	27	Fracture inferior pole of patella; posterior dislocation of knee	No fracture	8	4	Mild pains
5	21	.....	No fracture	..	2	No follow-up
6	20	Lacerated wound knee	Serration, posterior rim	8	3	No symptoms
7	51	Fracture upper tibia, fibula and patella; posterior dislocation knee	Avulsion-chip fracture femur	12	6	No symptoms
8	33	Dislocation mid-tarsal	No fracture	8	4	Mild pains
9	20	.....	Avulsion-chip fracture femur	8	2	Night pain
10	25	.....	No fracture	6	Unknown	No follow-up
11	24	.....	Avulsion-chip fracture inferior rim	8	3	No follow-up
12	20	Lacerated wound knee	No fractures	4	4	No symptoms
13	20	.....	Undisplaced, incomplete rim fracture	8	3	No symptoms
14	21	.....	.....	8	3	No follow-up
15	19	Lacerated wound knee	Fracture pubic symphysis	5	Unknown	No follow-up

exceptions all the cases in this series occurred in automobile accidents, with the jeep, as already noted, responsible for most of the casualties. Although soldiers were constantly involved in accidents in tanks, aircraft, trucks and other types of mechanized vehicles, under conditions which seemed equally hazardous, dislocations of the hip were seldom the result. The U. S. Army Truck, ¼ ton, more popularly called the "jeep" or the "peep," seems to possess special structural characteristics which put the soldier in a favorable anatomic position for the production of this special injury. The fact that this vehicle was the most commonly used in the U. S. Army cannot be overlooked as an explanation of the relatively high incidence of dislocations of the hip in Army experience. On the other hand, the impression was gained from communications with other surgeons working in other theaters of operations, who saw very few such injuries, that the concrete jeep provided the exact conditions which experimental observations[1,2,38] have shown are necessary for the production of dislocations of the hip joint. (Fig. 2.) This vehicle, which during the war served admirably the purposes for which it was constructed, is similar in design to the old-fashioned wagon in that it has a minimum of protective framework and that passengers readily fall out of it. Its low seats necessarily require that the hips of the passenger be flexed more acutely than they are in other automobiles; it is while they are in an acute flexion that the head of the femur is in internal rotation, directly posteriorly, and disposed toward posterior dislocation. The instrument board or the back of the front seat is so close to the passenger's flexed knees that it is difficult to avoid the "dashboard" blow which has been described by so many writers as one of the classical patterns of modern injuries. The jeep itself, therefore, may be assumed to

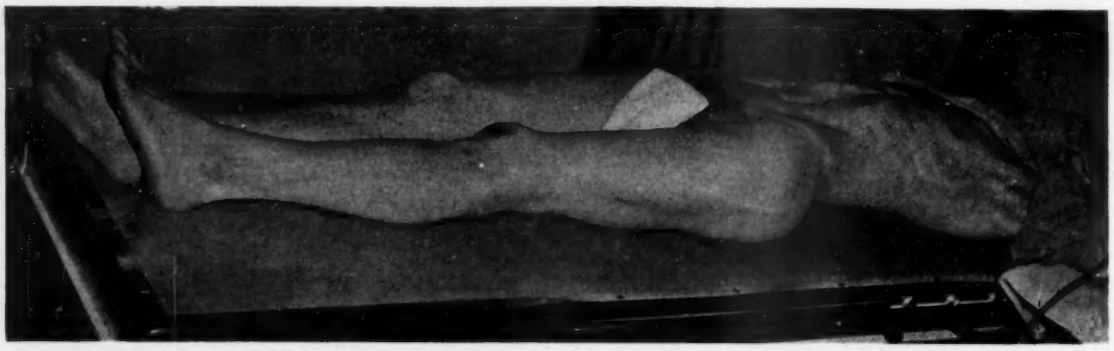


FIG. 1. Typical posterior dislocation of hip as result of jeep accident. Note unequal length of leg, internal rotation of knee and adduction of hip. Note also severe bruises in prepatellar region on both sides.

be primarily responsible for the appearance of a large number of dislocations of the hip over a period of eighteen months when ordinarily it would take many years to collect a series of this size.

on the floorboard, or it may come from behind and be transmitted to the hip by the sacrum. Fractures of the rim of the acetabulum have been reported to follow blows on the trochanter; and central fractures, which ordinarily

FIG. 2. Artist's interpretation of patients' own description of their positions and attitudes at the time of the injury. The accident was usually a head-on collision with resulting dislocations and fractures of the hip joint. A, inside-sitting position, the rider may have fallen out, striking the pelvis and incurring a fracture-dislocation or fracture. B, soldier sitting with legs abducted; in event of collison and dashboard blow on knee, may also have sustained fracture of the acetabulum or a fracture-dislocation. C, if rider was sitting with hips acutely flexed and adducted, the head of the femur may have dislocated with minimum or little damage to bony rim of the acetabulum.

Clinical and experimental evidence suggests that the nature of the injury in this type of accident is determined to some extent by the position of the joint at the time of injury. The blow may be received by the greater trochanter or be transmitted through the femur from the flexed knee on the dashboard or from the foot

are assumed to occur from this type of blow, have occurred from blows transmitted from the flexed knee or the extended leg when the hip was widely abducted. When the hip is adducted and flexed, as it is in a man riding in a jeep, perhaps with his legs crossed, the head may exit from the joint with minimum damage to

the bony structures, the result being an ordinary dislocation without a gross fracture.

TRAUMATIC LESIONS

The obvious traumatic lesions in these fifteen dislocations of the hip were chiefly injuries of the soft parts of the joint. Since in every case the method of treatment was closed manipulation, there were no opportunities to observe the lesions directly as there were at operations for fracture-dislocations. This is, of course, unfortunate in the sense that observations in fresh cases would supply knowledge concerning the differences in individual cases which determine the occurrence of avascular necrosis, another serious manifestation of this injury. A careful examination of the roentgenograms in these dislocations, however, in the light of the accumulated experience with experimental dislocations,[1,2,38] reveals certain details which seem significant and which may be relevant to this problem.

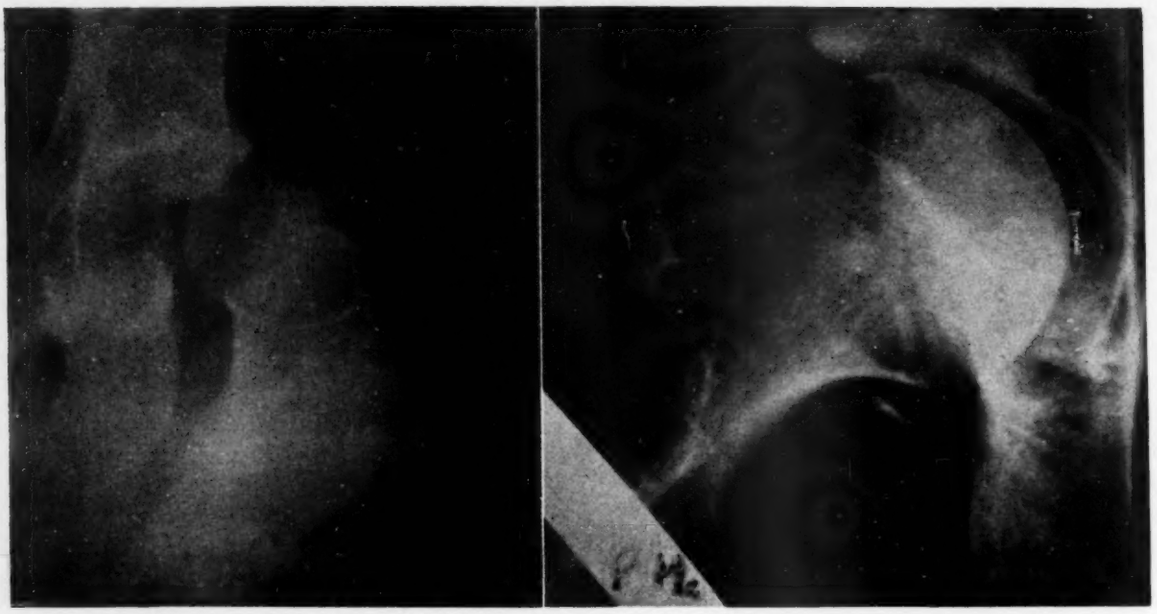
The roentgenologic location of avulsion chip fractures or serrations of the rim in three cases (Cases 2, 6 and 11) suggests that the capsule may have been torn at the acetabular attachment of the joint capsule. (Figs. 3 and 4.) In other cases (Cases 7 and 9), because of avulsion fractures in the posterior intertorchanteric region, the femoral attachment of the capsule was torn. (Figs. 5 and 6.) Allis[1] fully described both types of capsular lesions in his study of experimental dislocations. The possible relationship of the location of the capsular tear and the damage to the blood supply, particularly to the branches of the medial circumflex femoral artery which enter the hip joint in the intertrochanteric area posteriorly, merits further investigation.

Prereduction or postreduction roentgenograms also revealed other minor fractures which took the form of incomplete fissure fractures of the edge of the posterior acetabular rim. In fact, there were only eight cases among the forty-two dislocations and fracture-dislocations in the whole series of fifty-eight cases in which there was no evidence whatsoever of bone damage. Since roentgenograms of the hip joint usually show only gross defects, some damage to the rim and head of the femur may reasonably be assumed in every instance of dislocation. Observations at operations on fracture-dislocations demonstrate that some damage is usually sustained by the articular cartilage. Dislocations without major fractures usually damage the soft parts and parietal capsule more extensively than do those which break the bony structure.

Dollinger's[12] description of the traumatic lesion in twelve instances of inveterate dislocation which was observed at operation is one of the most complete on record. Tears were observed in all the posterior muscles, including the quadratus femoris. A survey of the few autopsied cases[2,8,24,46] and some remarks about findings at operation on irreductible dislocations[22,33,36,39,49,51] in the older literature suggests that in these injuries the head of the femur most frequently escapes between the piriformis and obturator internus, tears the fragile gemelli muscles and comes to rest with the more durable obturator tendons stretched over and under the protruding neck of the femur. Damage to the intertrochanteric attachment of the posterior capsule at the insertion of these muscles, the point at which the largest part of the blood supply enters the hip, seems never to have been observed. Avulsion fractures repeatedly observed in this region in postreduction roentgenograms supply sound evidence that such damage occurs and should be searched for.

The position of the head of the femur, as determined by the position of the lower extremity, furnished the basis for the early classification of dislocations of the hip as well as for the clinical diagnosis during the pre-roentgen age. Cooper,[8] in 1844, listed five different types of traumatic dislocation of the hip; Malgaigne,[27] in 1855, suggested seven, namely, iliac, ischiatic, supracotyloid, subcotyloid, perineal, ischiopubic and iliopubic, named in counterclockwise order around the acetabulum. He also recognized mixed types such as complicated and complex, The advent of roentgenology made clear that many of these types were chiefly theoretic possibilities and that the most important consideration is whether the dislocated head is anterior or posterior to the acetabulum. Bigelow's postmortem studies[2] showed that the Y ligament is usually intact in posterior dislocations (his so-called regular dislocations). He depended upon this ligament to serve as a fulcrum for circumduction in the manipulations which he advocated.

When no fracture is present, the head of the femur probably does not displace farther than just over the rim of the acetabulum. This was



3 4

FIG. 3. Emergency roentgenogram of posterior dislocation of hip joint. Film is of average quality. In such films there was often no bone detail and fractures were not suspected (Case 11).

FIG. 4. Roentgenogram after manipulation and reduction of dislocation by Stimson's maneuver, showing avulsion-chip fracture, probably of interior posterior rim of acetabulum. The acetabular attachment of the joint capsule has presumably been torn away. Note improvement in quality of film.

its position in all fifteen cases in this series. A case reported by Kleinberg[21] suggests that the excursion of the head may be less than the length of the ligamentum teres. If the head escapes by way of the cotyloid notch, this ligament may not be torn, a possibility easily verified by a fresh anatomic preparation of a hip joint after circumcision of the capsule.

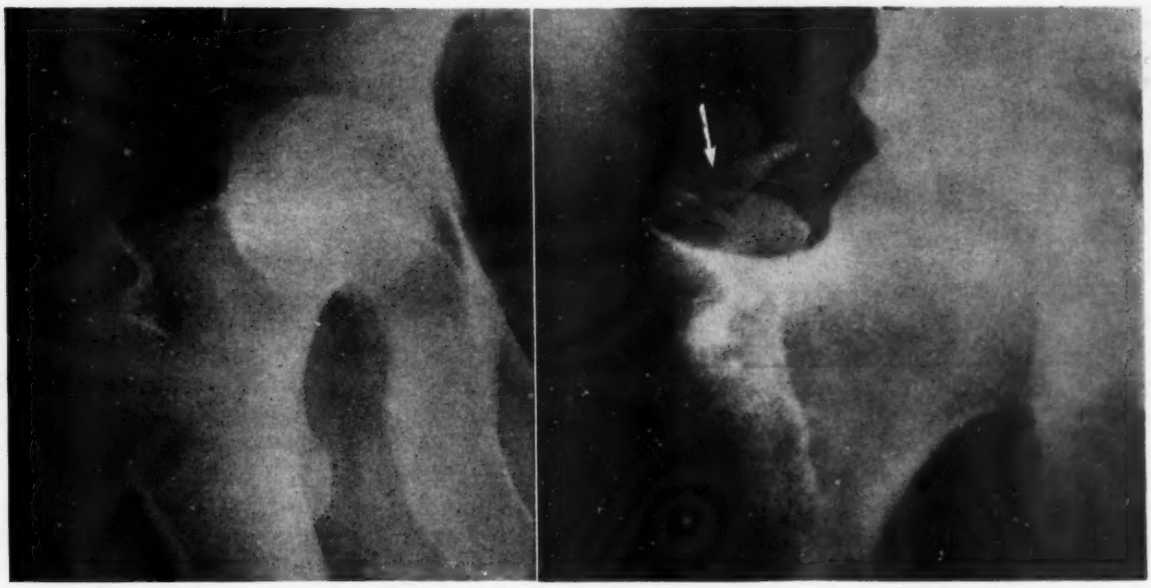
The single anterior dislocation in this series resembles those reported in recent literature.[5,25,40] The head of the femur rested opposite the obturator foramen but its position could not be determined by rectal examination.[16] Dislocation of the head into the scrotum and similar bizarre displacements are illustrations of Bigelow's irregular types[2] of dislocation. There were no such cases in this series. Sixty-two cases of bilateral dislocations of the hip, representing various types, have been reported in recent years but individually the lesions are the same as in ordinary cases.[28,50]

TREATMENT

Emergency Measures. Because of the striking clinical picture and the obvious deformity, most of these fifteen dislocations were promptly recognized in battalion aid stations and field hospitals. Occasionally, an attempt was made to mobilize the extremity by the use of a Thomas splint. More often preventive treatment for shock was instituted and the leg was simply bandaged to the litter; or the patient protected himself against further trauma until the diagnosis was confirmed by roentgenology and the dislocation was reduced. Six of the patients had severe injuries of other parts of the ipsilateral extremity which also required immobilization.

Reduction. All fifteen dislocations were reduced, apparently without difficulty, by relatively inexperienced surgeons. While no definite statements appeared on the record as to the number of attempts or the length of time required to achieve the results, sodium pentothal alone was used in twelve of thirteen cases which suggests reasonably prompt success. In the fourteenth case the dislocation reduced spontaneously without anesthesia; this patient was in shock and all four extremities were injured. In the fifteenth case the first attempt at reduction was unsuccessful and a second surgeon later reduced the dislocation; pentothal anesthesia was employed for both manipulations.

Five dislocations were successfully reduced at the first attempt by Stimson's maneuver, which was also later employed in two other



5 6

Fig. 5. Emergency roentgenogram of posterior dislocation, showing suspected fracture of femur (Case 7).
Fig. 6. Post-reduction roentgenogram, showing avulsion fracture of superior portion of intertrochanteric ridge, which is in the line of the femoral attachment of joint capsule posteriorly.

cases, after unsuccessful manipulation by the Bigelow circumduction method and the Allis supine method. Stimson's technic[47] was closely followed. Nothing was done until the muscles were fully relaxed. Then the thigh was slightly rocked to and fro which amounted to gentle internal and external rotation. In all the instances in which the method was used, the head of the femur promptly slid down into the acetabulum. The weight of the hanging limb plus a little downward pressure on the posterior upper tibia supplies the needed traction. The single anterior dislocation in this series was easily reduced, with the patient supine, by the reverse-circumduction method of Bigelow.

Reports in the older literature indicate that dislocations are easy for experienced surgeons to reduce by any method if there are no obstacles in the pathway of the displaced femoral head and if the acetabulum has not been distorted.[2,10] Ambroise Paré[35] and surgeons of early medical history leading up to the time of Sir Astley Cooper[8] and even later stretched the joint capsule and muscles and accomplished forcible reduction, without much difficulty in the majority of cases, by traction with the block and tackle. But strong traction has been regarded as unnecessary and even harmful since Bigelow emphasized the importance of flexing the hip to relax the Y ligament. After the joint has been properly flexed and muscular relaxation has been obtained under anesthesia (spinal, if that type is preferred), reduction has frequently been achieved with gravity alone and has even been reported to occur spontaneously. Allis reported the successful use of the gravity method in cases in which he could not reduce the dislocation by any of the methods he usually employed and Bigelow also reported a successful reduction with gravity in the prone position. The patient was a twelve year old girl with whom he had failed six or seven times with the circumduction maneuver.

The Allis,[1] Bigelow,[2] and Stimson[48] methods, all described by American surgeons, are all effective in reducing dislocations of the hip in the majority of cases. Few of the many modifications of the Bigelow[29] and Allis methods[3,11,34] are generally known and most of them were therefore not tested in World War II. Stimson's method or one of its variations[13] is obviously the simplest and gentlest method of obtaining traction as many observers have testified.[20,23,46] The satisfactory results achieved with it in World War II suggest that inexperienced surgeons would always do well to start with Stimson's method. An experienced hip surgeon[41] would not use standard manipulations but would base his procedure on the clinical and roentgenologic findings in the special case.

Immobilization. One patient in this series was transported with the legs bound together in

a swath. Five, chiefly those who had suffered fractures and other injuries of distal joints of the same extremity, were evacuated in plaster of paris hip spicas. In the other nine cases complete recumbency was enforced for evacuation but immobilization was not employed.

When the patients were received at general hospitals at periods varying from a few hours to ten days after injury, they were treated in skin traction (bilateral Buck's extension or Russell's suspension) or by skeletal traction (by a Kirschner wire through the tibial tubercle) with 10 pounds' pull. Traction was employed arbitrarily as being the most logical form of treatment. There were no special Army directives for the management of unusual injuries such as these and there is also no uniform teaching on the subject.

Traction was employed for periods varying from four to eight weeks. The wide variation was not intentional but was due to irregularities in the evacuation schedule caused by the weather and the tactical situation in the European Theater of Operations. All patients were candidates for evacuation since they were considered to be in need of treatment for a year or longer at the least and were, therefore, ineligible for further duty in a combat area.

Six weeks was regarded as the optimum period of traction since the joint capsule and the ligaments require that period of time for complete healing. The rationale of treatment, in view of the complications which could arise from injury to vascular structures of the hip joint, was that maintenance of the circulation and healing of blood vessels would be aided by rest in traction.

The teaching on the subject, as already noted, is widely variable and the physician must formulate his own policies as to postoperative immobilization after traumatic dislocation of the hip. Equally experienced surgeons recommend that a hip spica be applied for two, three,[43,52] four[23] and eight weeks,[6] or that traction be applied for two, three,[15,44] or four weeks,[7,17] or that the patient be kept at rest in bed with no restriction of motion at all.[14,26,31,32,37,44] There is no evidence that the end results were any better when traction was employed for six weeks, as it was in this series, or that it modified convalescence at all. On the other hand, there is no basis for comparison of these cases with other cases since control studies on treatment and end results have apparently never been published. There were no instances of avascular necrosis and degenerative arthritis among these fifteen dislocations but their absence may be only coincidental. These complications were observed in the cases of fracture-dislocations in this series and no claims can be made that their absence in this small group of simple dislocations had anything at all to do with treatment. The literature suggests that avascular necrosis is apparently almost as common in simple dislocations as in fracture-dislocations, although many reports do not mention the presence of associated fractures and end results do not seem to have been evaluated on that basis.

Weight-bearing. All patients were evacuated to the Zone of Interior with instructions not to put weight on the injured hip earlier than six months after injury unless they were specifically instructed to do so by a medical officer who had examined a recent roentgenogram. They were informed of possible complications of dislocations of the hip and were told categorically that weight-bearing might be detrimental to recovery and that crutches should be used for a period of six months at least. As might have been expected, either the patient's own restlessness or the advice of other medical officers encouraged weight-bearing as early as three months in about half of the cases. Only the patients with associated fractures of the knee or foot are known to have refrained from weight-bearing for six months or longer.

Again there is no control series of cases on which to formulate opinions as to the value of weight-bearing. It has been arbitrarily withheld, according to the literature, for periods ranging from four to six weeks up to six months. There is no evidence to suggest, either from the literature or from the fifteen cases in this series, that it is detrimental to recovery in the majority of patients or that it contributes to the development of complications. There is, however, some evidence in the literature to suggest that established complications as avascular necrosis, ossification of the joint capsule and degenerative arthritis are symptomatically aggravated by it. Restricted weight-bearing is generally believed to produce disuse atrophy of the base of the neck of the femur, which accentuates the density of the dead parts of the head and thereby aids in the early diagnosis of avascular necrosis.

FOLLOW-UP STUDIES

The value of the methods of treatment used in these fifteen consecutive cases of ordinary dislocations can be determined only by their end results; however, many writers do not believe the end results can be stated conclusively until five to ten years after injury to allow time for possible development of degenerative arthritis. A group of 370 traumatic dislocations, reported in the literature and reviewed for purposes of this study in the third paper of this series, shows that aseptic necrosis usually occurs within two years. As a matter of fact, very few cases have been followed for longer periods of time.

TABLE II

SELECTED TRAUMATIC DISLOCATIONS OF THE HIP JOINT AT MASSACHUSETTS GENERAL HOSPITAL, 1931–1947

No.	Age	Other Injuries of Ipsilateral Extremity	X-ray	Treatment	Follow-up
232707	11	Sciatic nerve contusion, temporary peroneal palsy	Posterior dislocation	Non-weight-bearing caliper splint 6 mo.	Normal hip at 7 yr.
13739	14	.....	Posterior dislocation	Crutches 3 mo.	Avascular necrosis and complete collapse of femoral head at 18 mo.
225358	18	.....	Posterior dislocation	Bed rest 8 wk.	Normal hip at 2 yr.
330426	22	Head injury; fracture shaft femur	Posterior dislocation hip fracture rim acetabulum	Reduction in Soutter apparatus; bed rest 6 mo.	Occasional mild joint pains; normal x-ray at 5 yr.
235958	28	.....	Anterior dislocation	Hip spica 3 wk.	Night pain and slight limitation of motion in joint at 5 yr.; normal x-ray
543012	35	.....	Anterior dislocation	Bed rest 3 wk.	Normal hip at 1 yr.
399281	22	.....	Posterior dislocation	Hip spica 2 wk.; crutches 6 wk.	Normal hip at 4 yr.

It was possible at the end of two years to locate only nine of the fifteen patients in this series. In order to compare the results achieved in these nine cases with results in patients with similar injuries who have been treated, as is usual in civilian practice by shorter periods of immobilization and early weight-bearing, seven cases were selected from the Fracture Service of the Massachusetts General Hospital. (Table II.) These patients were examined at intervals of time varying from one to seven years.

A comparative analysis of the two groups of patients shows the same results. There were no immediate benefits derived from the extended period in traction and the extended restriction of weight-bearing practiced in the military cases. Five of the nine patients in the military group and two of the seven patients in the civilian group complained of slight aches and pains in the joints at irregular intervals. The patients in both groups who did hard labor or farm work were uncomfortable when they had to lift heavy objects. Four of the patients in both groups, during the first few months of weight-bearing, complained of pains in the joint in rainy weather, when they were climbing stairs and when engaged in sports, but they were free of these symptoms at the end of two years. One patient had night pain but the roentgenogram, being entirely negative, showed no cause for it. One patient, a fourteen year old boy, had developed avascular necrosis of the head of the femur before the end of one year. The poor result in this case must be disqualified somewhat because necrosis occurs more commonly in dislocations in patients in the adolescent age group. There was no evidence of degenerative arthritis in three other civilian patients examined from five to seven years after injury.

SUMMARY AND CONCLUSIONS

1. This paper is concerned with an analysis of fifteen dislocations of the hip, without major fractures of the head of the femur or acetab-

ulum which occurred in the European Theater of Operations chiefly as the result of jeep accidents. Fourteen were posterior and one anterior.

2. Reduction was accomplished without difficulty in all cases by relatively inexperienced surgeons. Stimson's maneuver (prone position-gravity method) was uniformly successful in this series and is recommended for the first attempt at reduction of posterior dislocations.

3. Avulsion chip fractures, which were usually unrecognized in emergency films, were observed at the femoral and acetabular attachments of the joint capsule in technically perfect postreduction roentgenograms. The femoral fractures may indicate injury to the blood supply of the joint, particularly the intertrochanteric branches of the medial circumflex femoral artery, and patients in whom they are observed may require closer observation for late complications.

4. Nine military patients who could be located at the end of two years were compared with seven civilian patients treated on the fracture service of the Massachusetts General Hospital and examined from one to seven years after injury. Prolonged traction and longer restriction of weight-bearing in the military cases produced approximately the same results as shorter periods of immobilization and early crutch-walking in civilian cases. Although only tentative conclusions are possible from two-year end results, the uniformly good results in all except one patient at this time do not encourage restriction of weight-bearing as a routine measure beyond six to eight weeks, the period with which the joint capsule might be expected to heal. Close observation, protected weight-bearing and perhaps traction and bed rest at home might be advisable in individual cases as soon as roentgenograms suggest avascular necrosis or if there are persistent signs of joint irritation, muscle spasm and limitation of motion. A routine policy of restriction from weight-bearing in order to obtain early diagnosis of avascular necrosis was impossible to enforce in healthy young men.

Acknowledgments Col. Mather Cleveland, M. C., Senior Consultant in Orthopedic Surgery, European Theatre of Operation, 1945, sponsored the work and offered advice or encouragement. The author is indebted to Dr. E. F. Cave, Dr. George Van Gorder and Dr. Henry Marble for their aid in securing the follow-up data on the dislocations of the hip joint treated at the Massachusetts General Hospital.

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DISCUSSION

Henry H. Ritter (New York, N. Y.): I am very grateful to have had the privilege of listening to Dr. Urist's paper and enter into discussion of it. I regret that I did not have his paper before me when I was asked to discuss it. However, there is not very much to add to what he has said except to emphasize some of the points he has already brought out.

I do not believe that I have seen in the past twenty years the number of cases of dislocation of the hip that Dr. Urist has seen in a very short period of time. In our series of cases, we have seen no anterior dislocations and I do not know whether or not he saw any. None of his radiographs presented today showed any anterior dislocation.

The majority of cases that we have seen were central dislocations. We had a few posterior dislocations due to dashboard accidents and some due to falls from a height.

I think it is well to bear in mind that at no time does one-half of the head of the femur articulate with the acetabulum, that when the hip is flexed less of the head articulates with the acetabulum and, when the hip is flexed and the limb adducted, the head is relatively unprotected by the acetabulum and rests upon the posterior capsule of the joint. I believe that explains readily the dashboard dislocations and I think it explains, too, that when the hip is flexed and the limb is adducted dislocations usually take place without a fracture of the rim of the acetabulum; whereas if the hip is flexed and the limb not adducted, a fracture of the acetabulum is associated with the dislocation.

Again, I want to thank Dr. Urist. I want to call attention to just one more fact. We have had some trouble with aseptic necrosis and destructive arthritis of the hip and we are trying something new. We cannot pass comment on it yet as it is too soon to say but we have been using procaine intravenously and we believe that we are having less muscle spasm and are able to get greater motion in these hip joints

without pain. No definite claims are made for intravenous procaine at this time.

Thomas B. Quigley (Boston, Mass.): It was my privilege to be associated with Dr. Urist during the first part of this work which you have heard.

These injuries, although common in military service, are not too common, as he has pointed out, in civilian life. However, they do occur and I am going to show you slides illustrating one case which occurred last December.

As you have seen, the only photograph of the hip joint exposed at operation that Dr. Urist was able to obtain was one which I took with an inexpensive camera. Our facilities were not very good in the situation in which we were placed. This civilian case, however, gave us an opportunity to take some color photographs of the operative approach.*

Henry C. Marble (Boston, Mass.): This is an interesting problem and it has been given to you in an interesting way. Dislocations of the hip in the old days must have been common. For the life of me, I do not know why because the problem of deacceleration and fast-moving vehicles was not the same.

In the old operating room at the Massachusetts General Hospital, we still have the block-and-tackle holds in the roof and the block-and-tackle holds in the floor where these patients were strapped down and turn-buckles and block-and-tackles attached and the dislocation was then torn into place. They must have been common.

Then, somewhat later, some of the older surgeons, particularly Bigelow and Allis, showed how these dislocations might be reduced by simple manipulation. Thereafter, in my house officer days, a dislocation of the hip was the prerogative of the senior surgeon; he always came down and there was a great ceremony of getting the patient ready. Then the senior surgeon, with considerable theatricals, took hold of the leg and everybody stood by and, after practicing a little shadow-boxing, he deftly and neatly put the hip back into place, and everybody bowed and the senior surgeon was then driven home in his carriage. That was the common procedure.

Once in a while, the senior surgeon, after his shadow-boxing and after his deft maneuvers, had not reduced the fracture. He then took his coat off and tackled it again and the patient was put under more adequate anesthesia. It was common practice to curse the anesthetist because he had not given you sufficient relaxation. He then tried again and again. And so we learned that there were two kinds of dislocation of the hip: the hip that went in easily and the hip that went in hard; and we discovered that the hips that went in easily did pretty well and the hips that went in hard did not do so well.

* Dr. Quigley showed a number of illustrations and explained each.

Now, Dr. Urist has come and told you in a word what happens and why we had certain hips that did not reduce easily. They were the fracture cases that he has shown. When Dr. Urist first told me about this, I said: "But I didn't devise it, it has been told me all of my medical life. Did the hip go in easily?" and he looked at me and said, "No, nobody could get it in." That was the answer. That lip of acetabulum was like the wedge in the door and not until that was removed, as you all heard—and I did not see a single person asleep—you learned that the way to put that wedge back in place is by the proper approach.

For us from Boston to talk about the posterior approach, I admit, is almost heresy; but as you see from what Dr. Urist tells you it is the only proper approach for fractures of the posterior lip of the acetabulum. Dr. Urist has looked up for me some of the cases which we have had.

We talk about dislocations of the hip very glibly. Since 1931, we have found the amazing number of seven cases on which we could get end results.

He finds that those seven cases that were in civilian practice, in general, have done well. Six of them did very well. The patients, the youngest eleven and the oldest thirty-five, were all young adults. They had minimal bed rest after dislocation. They were weight-bearing in from four to six or eight weeks, and of the seven, six had good hips. The x-rays showed no degeneration. Only one of the seven patients had avascular necrosis.

Homer H. Stryker (Kalamazoo, Mich.): I think just a word ought to be mentioned about the orthopedic problem that follows many of these cases, namely, sterile necrosis.

This happens in a certain percentage of dislocations without fracture or in some of those with fracture. I think if any of you have tried to fuse these by the intra-articular method, while there is still sterile necrosis, you are apt to meet with disaster. I think Sir Watson-Jones has mentioned that. I think you either have to wait a period of about two years until the head has revascularized or else do an extra-articular fusion.

I have had pretty good luck with these by taking pretty large slabs from the external plate of the ilium and fusing it to the greater trochanter, ignoring the head and neck pretty much altogether. Or I suppose the Brittain type of arthrodesis could be used. But these are fractures that occur in young men and as soon as sterile necrosis takes place, I think fusion is the answer. The necrosis must be kept in mind when doing this fusion.

Marshall R. Urist (closing): I wish to thank everybody for the very kind discussion and to add a few remarks. In reply to Dr. Ritter I can report that we had one anterior dislocation, the obturator type, and it was incurred presumably by forceful abduction of both hips. This dislocation was easily

reduced by the reversing of the circumdiction maneuver of Bigelow.

Dr. Quigley's patient was the only postwar civilian fracture-dislocation that we have observed under treatment. An extensive fracture with distortion of the acetabulum prevented the reduction by closed methods. At open operation as soon as the main fragments were disengaged, the head of the femur fell forward into its normal position in the joint. Dr. Quigley was then able to fortify the reduction with internal fixation of a posterior rim fragment and get a beautiful picture of the repair by x-ray.

Although by these somewhat spectacular operations we have given our patients a functional hip joint within six months, we do not know what is in store for them in years to come. A five-year follow-up is to be desired. How many and which types will develop degenerative arthritis is yet to be determined. It is consoling, however, to find that in 370 cases reported in the literature, the disastrous complication of avascular necrosis occurred within eighteen months of the time of the injury. Hence we assume from two-year follow-up reports that we know the result with respect to this problem in thirty-eight cases.

Dr. Marble reviewed the problems of treatment with me last winter while the results were coming in and kindly offered many helpful suggestions. His experiences closely resemble those which are found in the older American literature. The nineteenth century surgeons apparently knew much more about this injury than we do in modern times. I have studied their descriptions of autopsy and experimental necropsy specimens. We are, at this time when trauma is autopsied mainly by the medical examiner and rarely by the academic investigator, indebted to the pioneer surgeons for the only information on record about the nature of the traumatic lesion.

Dr. Stryker, who quoted Watson-Jones, presents a point of variance from our views in which he believes that these patients should not have an intra-articular hip fusion until we know whether avascular necrosis will occur. We found that this complication is not so common as to be a deterent factor in early treatment. We are inclined to think that the rich blood supply of the ilium can be transmitted to the avascular head, thereby possibly cancelling the effects of the necrosis and perhaps even saving leg length. After all, every bone graft is an area of avascular necrosis. For those reasons and many experiences in which we have observed the surgeon completely denude the head of the femur, excise the joint capsul and readily obtain fusion, I would favor early erasion of the joint for irreducible dislocations with extensive comminuted fractures of the acetabulum in active young men. In suitable cases an arthroplasty can be done at a later time if joint motion is required by the individual patient.

JOINT MOBILIZING OPERATIONS ON THE HIP, KNEE AND SHOULDER FOR COMPLICATIONS FOLLOWING TRAUMA

PAUL H. HARMON, M.D.
Oakland, California

FRACTURES into a joint are regularly followed by degeneration of the joint cartilage. After a variable period, such a joint becomes the seat of a presenile degenerative osteoarthritis, the pathologic findings of which are indistinguishable from those of other types of degenerative joint disease. Indeed, there are certain instances of degenerative joint disease localized to a single joint that have a clear-cut antecedent history of either single or repeated minor trauma without osseous fracture. Example of degenerative joint disease following trauma, with or without fracture, are best known in the hip joint where the aseptic changes in the femoral head, and consequently in the overlying articular cartilage, follow with a certain regularity in cases of fracture of the femoral neck and dislocation of the hip. Less well known is the degenerative arthritis of the hip joint following acetabular fracture and following single or multiple severe trauma to the hip region. In groups of cases of degenerative arthritis of the hip, in which antecedent histories and roetngenograms were available, many revealed a definite causative factor, often trauma, (Plewes, 126 of 242 cases, 52 per cent; Harmon, 37 of 94 cases, 39.4 per cent).

In the series of cases of hip joint arthritis herein reported, twenty-two of thirty-five cases (62.8 per cent), trauma with or without definite fracture was the likely precipitating cause of degenerative arthritis. Little is known about the exact incidence of degenerative arthritis of the hip joint. Boyd and George reported an incidence of 33.6 per cent aseptic necrosis (41 of 122 cases) following within one to two years after union in transcervical fracture of the femur; 14.6 per cent of the whole series had "severe arthritic" change. Pfab stated that 8.3 per cent of twenty-four cases of uncomplicated hip joint dislocation developed aseptic necrosis of the femoral head.

In the other major joints, chondromalacia of the patella and marginal fractures are known to be definitely related to trauma, but the sequence of events is not clear. Chronic trauma, such as often repeated injury of occupations as seen in the shoulders of baseball pitchers and glass blowers, can also precede degenerative arthritis of that joint. The results from surgical treatment of instances of all these conditions will be presented in this paper. Palliative and conservative treatment will not be considered, but the results from operations designed to decrease pain and secure additional motion in the hip, knee and shoulder joints will be described. For the hip, end results will be presented for cup arthroplasty and from excision of exostoses from acetabulum and femoral head. For the knee, results will be given for a modification of the Magnuson joint débridement operation. For the shoulder, results for partial resection of the humeral head and for removal of posterior glenoidal exostoses

TABLE 1
SUMMARY OF RESULTS FROM HIP MOBILIZING OPERATIONS IN UNILATERAL DEGENERATIVE HIP DISEASE FOLLOWING TRAUMA

	No. of Cases	Good	Fair	Poor*
Results from operating upon femoral head—thin plastic cups				
1. Degenerative arthritis following fracture	6	4	1	1
2. Degenerative arthritis following epiphysiolysis	4	3	0	1
3. Degenerative arthritis following trauma without initial demonstrable fracture	6	3	2	1
4. Aseptic necrosis of femoral head following dislocation of hip	2	1	1	0
5. Ankylosed hips (unilateral) following pyogenic arthritis of hip complicating compound injuries	3	0	0	3
Results from operating upon acetabulum—$\frac{3}{16}$ inch plastic cups turned from solid plastic all post—traumatic cases	8	7	1	0
Exostectomy upon femoral head and acetabulum without using interposition material	6	2	3	1†

* Two poor results were observed following fracture of the cups in the three first groups.

† Chief clinical results in this group were increase in motion with lessened pain.

in selected cases will be given. It should not be assumed that the operations described in this paper are applicable to all cases of degenerative arthritis of the joints in question or that they replace arthrodesis. Indeed, in the weight-bearing joints, the hip and knee, especially the hip, the selection of a patient for a joint mobilizing operation should be made on the criteria of age, temperament, occupation and desire for the procedure after the postoperative treatment and expectation have been explained. Arthrodesis still remains the method of choice in advanced degenerative arthritis, especially when the subject must be certain of a painless joint that will serve him without fail in such occupations as laboring, farming, etc.

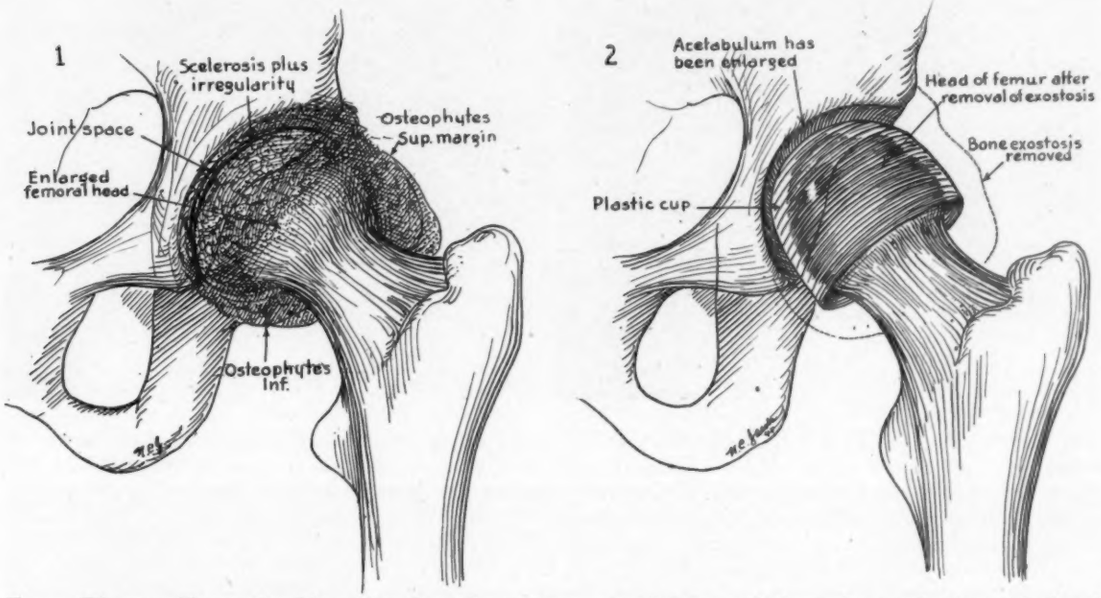


Fig. 1. Diagram illustrating hip arthroplasty by enlargement of the acetabulum when a plastic cup is fitted to the femoral head with minimal shaping of the femoral head. The clear space in the postoperative diagram represents the roentgen transparent "joint space" filled by the acrylic cup.

THE HIP

Summary of Results from the Literature. There are only three articles in the surgical literature which present a sufficient number of end results from cup arthroplasty on a single movable hip to warrant quotation for statistical purposes. Bickel, Ghormley et al., reporting on eighty-eight cases not fully segregated according to diagnosis, stated that 40.9 per cent were good, 28.4 per cent fair and 30.7 per cent poor. Badgley's statistics, corrected by removing cases of gonorrheal arthritis, pyogenic infection of the hip, tuberculosis and rheumatoid spondylitis, show on the remaining forty-eight hips that 64.9 per cent were good and very good results, 20.8 per cent fair results and 14.6 per cent poor results. Harmon, in a previous report, gave 71.4 per cent good and very good results on twenty-one hips and 14.3 per cent fair results.

The criteria for the grading of the end results were the same as those utilized by Bickel, Ghormley et al. and are based on function, relief of pain and mobility. "Very good" is essentially a normal hip with a range of motion of at least 90 degrees flexion, a variable amount of abduction-adduction and a painless hip allowing full weight-bearing. "Good" signifies patients who had little or no pain, occasionally utilized a cane, had a variable degree of abduction-adduction, but who presented a minimal disability made worse by excessive use of the hip and by weather changes. "Fair" is utilized to indicate improvement over the preoperative status, a variable amount of minor disability and pain but tests of passive motion indicating only a fair amount. These patients often had a fair amount of pain on excessive use and could not use the hip for prolonged and strenuous activity. "Poor" indicates either sufficient pain to render the person definitely disabled and was often accompanied by poor passive motion.

A B

FIG. 2. Roentgenograms at a ten-year interval illustrating the pathogenesis of degenerative osteoarthritis following single severe trauma without demonstrable fracture. A, the changes are subchondral sclerosis over the entire acetabulum with thickening of the mesial osseous acetabular wall, slight diminution of the joint space, especially in the weight-bearing portion of the joint, and the development of adductor and superior head-neck osteophytes. B, ten years later, the femoral head has been pushed out further laterally by proliferation of the mesial acetabular wall and by enlargement of osteophytes on the inferior head sector. The joint space has disappeared in the weight-bearing portion of the joint and the superior margin of the femoral head has become continuous with the trochanter by filling of the neck surface by osteophytic new bone. In addition, there are extensive degenerative changes in the femoral head, microscopic sections from which show both infarcted osseous islands and endosteal proliferative changes to produce dense bone.

In the author's first series, part of which is also quoted in this paper, a patient originally rated as "poor" was often given a good or very good result by removal of the cup when a fracture occurred in a plastic cup or cup removal was performed for continued pain two years or more after the operation. This was also Badgley's experience. This fact is not taken into consideration in Table 1, as the results recorded there are as resulting from the cup insertion and not influenced by a secondary operation.

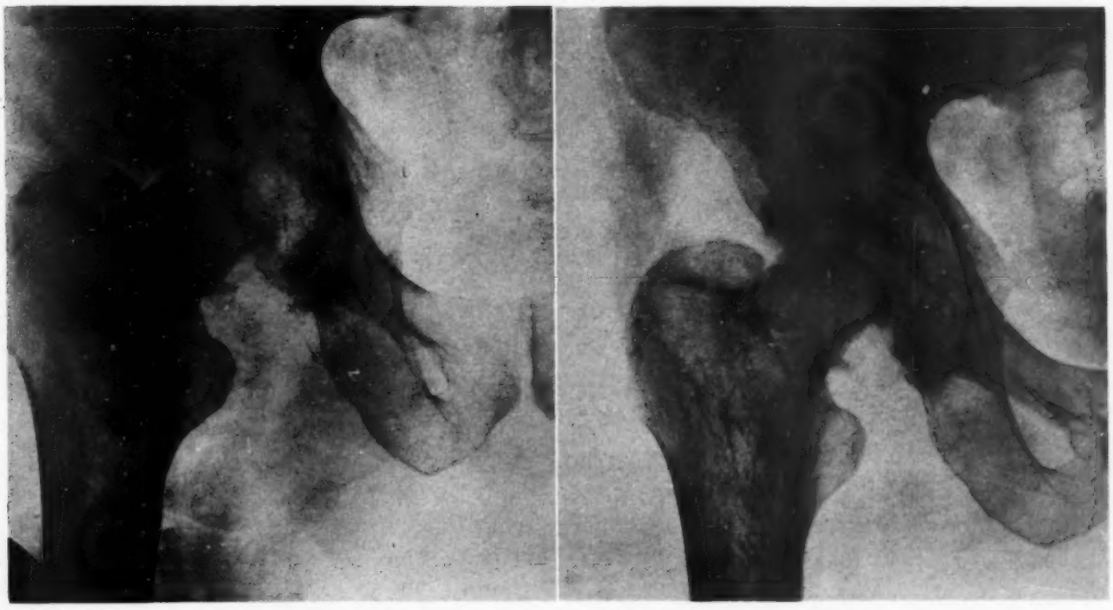
Both in Badgley's report and in our previous end result report, the results were found to be unsuitable in arthroplasty following previous pyogenic infection of the hip. In five arthroplasties for osseous ankylosis following healed septic hips, we had but a single (20 per cent) good result. In a similar number of cases, Badgley reported four (80 per cent) fair results and one (20 per cent) poor result. Bone altered by previous infection does not appear to withstand weight-bearing following hip arthroplasty since the cause for failure was late and gradual collapse of the head-neck stump.

Magnuson believed that all of the eleven hips upon which he performed joint débridement were improved, but the criteria of improvement and the time of the evaluation were not stated.

Operative Technic. The detailed operative technic (Fig. 1) for arthroplasty of the hip will not be repeated here, as it has already been given in the articles by Smith-Petersen, Harmon and Badgley. In the presence of a movable hip, we have always believed that the approach should be chiefly femoral, with a minimum of stripping and detachment of muscles from the anterior and lateral ilium. It is only absolutely necessary to divide or strip the tensor fascia femoris to expose the entire hip joint. Providing the subject is obese or stocky, detachment and downward reflection of the sartorius and the tendinous head of the rectus femoris will facilitate exposure. It is important clearly to expose the anterior, superior and adductor-inferior portions of the acetabulum, in order to remove accurately osteophytes and to judge the subsequent fit and motions of the cup in relation to the reconstructed femoral head and

A B

Fig. 3. Roentgenograms over a ten-year period in a patient with degenerative arthritis of the hip following acetabular fracture. A and B are preoperative; A, one year after fracture; B, five years after fracture. Note further sclerosis of the femoral head and thickening of the mesial acetabular wall both into the acetabulum and on the pelvic side.



C D

Fig. 3. C and D are postoperative, the "joint space" being occupied by an acrylic cup. C, one year after operation; D, four years postoperatively. Note surface sclerosis of the femoral head denoting satisfactory response to weight-bearing.

acetabulum. Minimal operating is done on the posterior acetabulum, but inspection and removal of osteophytes from the posterior femoral head, accomplished by manipulation after the head is dislocated, is quite important. It has been this author's conclusion, based on long term follow-up of the first series of cases that there should be minimal removal of osteophytes from the femoral head consistent with securing a perfectly rounded femoral head from which secondary and tertiary circumferences have been eliminated (Figs. 4 and 6) and that there should be no operating that might damage the reflected capsule on the

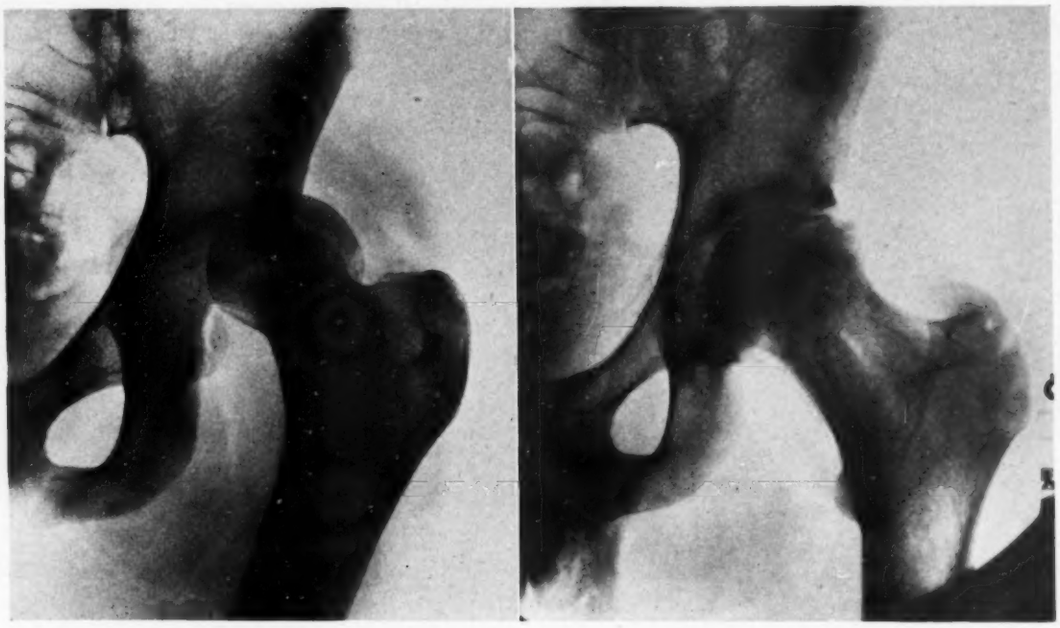
A B

FIG. 4. Preoperative (A) and one year following operation (B) for degenerative arthritis following single trauma. Here, in addition to actual enlargement of the femoral head and cartilage degeneration in the joint, there is massive and extensive proliferation of the acetabular margins. This confers an impression of diffuse, intense sclerosis to both femoral head and acetabular margins. At operation, about seven-eighths of the normal extra-acetabular portion of the femoral head was covered by a sheet of acetabular new bone, especially from the anterior and superior acetabular margins. Note in (B), the postoperative view, that the osseous texture of the femoral head is clear since the acetabular new bone had been removed.

femoral neck. If radical bone removal is necessary to secure the aim of a loose fit of head within the cup and cup within the acetabulum, this should be done by enlarging the acetabulum. Since the newer plastic cups are $\frac{3}{16}$ inch thick, this means more radical removal of bone when these cups are used. In a few cases (e.g., Figure 5, a case of aseptic insular necrosis with marked osteophyte formation in a young subject), we have utilized Vitallium cups with which acetabular reaming is minimal. In performing cup arthroplasty, the surgeon should have available a wide choice of sizes and styles of cups to secure the best result for each case under consideration. Preferred anesthesia is continuous fractional spinal with novocain crystals.

Since the end results on sixty-three hips in which thin methyl methacrylate cups molded from sheet plastic showed either fracture of the cup or excessive wearing in seven (11.1) per cent, we have revised the specifications for acrylic cups. The original cups were only $\frac{1}{8}$ inch thick. The cups now in use have all been turned from solid blocks of a slightly harder acrylic resin, to the uniform thickness of $\frac{3}{16}$ inch. We have had no fractured cups (thirty cases) since the newer type plastic cup has been in use (period of observation, six months to four years). Comparative tests on the two types of cups show that the forces required to rupture the cup from the inside and the external resistance to crush are approximately doubled in the newer cups. These latter values are of the magnitude of 400 to 800 pounds.

When the roentgenograms demonstrate slight to moderate narrowing of joint space, and inspection of the articular cartilage following osteophyte removal shows fairly good remaining cartilage with little or no pleat formation and little or no fibrillation, it is considered that this is a suitable case for the operation of exostectomy without dislocating the hip. Obviously, in instances of degenerative arthritis following trauma, the opportunity to carry out this latter type of operation is not frequently encountered. When the operation is performed, and there are complicated osteophyte systems on the posterior femoral head, these can be satisfactorily removed only in two stages, the second one of which is carried out



A B

Fig. 5. Roentgenograms in a case of aseptic necrosis of the femoral head in a young man of twenty years following dislocation of the hip. A, shows the dislocation. B, a roentgenogram made one year later showing diffuse and complete aseptic necrosis of the femoral head except where slight substitution has started at the superior and inferior angles with slight collapse of the head from weight-bearing at the superior pole. At operation a ring of osteophytic new bone was present 3/8 inch in height at the head-neck margins.

through a posterior approach. It should be pointed out that the conventional anteroposterior roentgenograms of the hip do not reveal clearly the full extent of the osteophyte systems in degenerative arthritis. Often the femoral head will appear to be of mottled density when the appearance is conferred by overhanging osteophytes from the acetabular margins. (Fig. 4, 6 and 8.) If the femoral head is missing or fused into the acetabulum with the upper femur more or less normal, a modified Whitman operation utilizing a cup for interposition is carried out.

We have eliminated complicated postoperative fixation apparatus and complicated apparatus for exercise, as the complicated systems have no advantage over the simple regimen now employed. Postoperative immobilization is by Buck's extension of five to seven pounds. A wide internal rotating strap of adhesive tape is fixed to the thigh. A diagonally directed counterweighting of three or four pounds is placed on the rotator strap. The patient is allowed to shift from side to side and to be up on the back rest as soon as he can comfortably do so. Precautions are taken that he does not turn or allow the leg which has

Fig. 5. C, a roentgenogram eight months following operation. At operation no cartilage was removed from the femoral head and only a thin film was removed by reaming the acetabulum. The patient began almost full weight-bearing six or eight weeks after operation without knowledge or consent of the surgeon, now has almost a full range of motion, lacking only complete abduction and rotation and has had only minor pain since he began weight-bearing after operation.

A B

FIG. 6. A and B, preoperative and postoperative roentgenograms in a fifty year old woman whose hip was the seat of degenerative osteoarthritis resulting from a congenitally inadequate acetabulum. The changes in the preoperative roentgenogram are proliferation of the intra-acetabular portion of the acetabular wall, dimunition of the weight-bearing joint space and subchondral sclerosis in both femoral head and acetabulum. Postoperatively, the femoral head dislocated at three weeks and an acetabular shelf was built from the ilium at a second operation. The postoperative film was made four years later. The "joint space" is filled with the acrylic cup and the patient has no pain and near full motion.

been operated on to fall into adduction. He begins to get out of bed in the wheel chair and to start exercise in the physical therapy department at two and one-half weeks. Walking with crutches without weight-bearing on the operated leg is initiated at three and one-half weeks and slight but minimal weight-bearing, at eight weeks. Crutches are not discarded and full weight taken on the hip for four to eight months, depending upon the nature of the operation (degree of removal of weight-bearing bone and cartilage). The postoperative schedule is accelerated by one week in cases of exostectomy of the hip without dislocation. When the weight-bearing cartilage is not disturbed and no interposition substances used in this latter group, full weight-bearing is allowed with crutches or cane four to six weeks after the operation, depending on the patient's ability.

Results from Hip Mobilizing Operations. The results from thirty-five cases are summarized in groups as follows:

A: Five, six and seven year end results from hip arthroplasty with one-eighth inch molded cups of methyl methacrylate in twenty-one cases with a traumatic background, subdivided according to etiology:

1. Six cases of unilateral degenerative arthritis following fracture in the region of the hip, mostly acetabular fracture.
2. Four cases of degenerative arthritis following adolescent joint disease, presumably epiphysiolysis.
3. Six cases of unilateral degenerative arthritis of the hip, the clinical onset of which closely followed a major traumatic history. Roentgenograms either failed to reveal initial fracture in these cases or no roentgenograms were made, and the evidence now at hand tends to rule out original fracture
4. Two cases of aseptic necrosis of the head of the femur complicating dislocation of the hip but without posterior marginal acetabular fracture. (Vitallium cup arthroplasty was performed in one case.)
5. Three cases of pyogenic arthritis of the hip with ankylosis, all being complications of compound injuries of the hip region.

In all of the above listed cases, the operative attack was primarily on the femoral head.

Only exostoses were removed from the acetabulum, which was smoothed but not enlarged.

B: One to three year end results from arthroplasty with methacrylate cups, 3/16 inch thickness, turned from solid plastic. The operation was primarily an enlargement of the acetabulum with minimal operating on the femoral head. All cases of unilateral degenerative arthritis followed trauma in the region of the hip, three of which complicated acetabular fracture.

C: Six cases of exostectomy of both femoral head and acetabular osteophytes without dislocation of the hip or use of interposition material. The end results are for variable periods, in one case, one year, in two cases, two years and in three cases, three years or more.

The results are summarized in Table 1. All results rated as "good" had stable hips with no or insignificant discomfort and had a gait which closely resembled normal. In about one-third of all good results, minimal discomfort resulted during weather changes and excessive use of the hip. The patients in all cases reported as good were well satisfied with the results. Roentgenograms in the first three groups taken at intervals over the five- to seven-year observation period showed a definite cause for the fair and poor results in nine of the ten cases in these two latter categories. The causes included gradual wearing away of the femoral head, further necrosis in this structure and fracture of the cup, this latter in two cases only. These changes in roentgenograms have been illustrated in a previous report. In a few cases, changes occurred in the femoral head with little or no symptoms occurring in the patient. (Fig. 3.)

It should be pointed out that the results have been uniformly good in the post-traumatic cases in which the major operative attack has been directed at the acetabulum (Table 1, item 6). So far, there have been no changes observed in the femoral heads in this group. It should also be pointed out that the results from exostectomy alone without the use of interposition material have turned out as palliative, chiefly consisting of considerable increase in motion. This latter result would be expected, because no change has been made in the contacted cartilage surfaces within the damaged joint. An insertion of a plastic cup has been done subsequently in two of these six cases with good results (period of observation, one to two years).

THE KNEE

Summary of Results from the Literature. Bennett and Bauer long ago pointed out the rôle of poor adaptation of the patella to the femoral condyles in producing degenerative change in the knee joint in recurrent dislocation of the patella and in genu valgum and genu varum. They suggested that the remaining changes in the joint were secondary to changes in the patella and to trauma by the diseased patella. Berkheiser reported on excision of the patella alone in eleven cases of arthritis of the knee joint. His best results were secured in degenerative and in post-traumatic arthritis. Haggart operated on twenty patients. The majority were treated by total patellectomy combined with synovectomy. He reported nineteen of twenty cases "markedly improved" by the procedure. Young and Regan reported on total excision of the patella in fourteen cases of osteoarthritis of the knee. In seven, excellent results were secured, the criteria being no pain and at least 80 degrees active motion. Four good, two fair and one poor result were secured in the remainder. Magnuson reported "extremely satisfactory" results in over 100 cases of joint débridement on the knee.

Operative Technic. The technic of joint débridement will not be described here, as this has already been given in detail by Magnuson. We have modified Magnuson's operation by removing all or a portion of the patella, preferably the posterior two-thirds of it, for the reason that it has appeared that the extra bulk of the patella in degenerative arthritis also serves to fill up the interior of the joint. (Figs. 9, 10, and 11.) Briefly, after the joint is opened, exostoses are removed with an osteotome from around the periphery of the condylar margins. This includes exposure of the lateral and inferior condylar margins on both tibia and femur, and also the intercondylar region of the femur in the region of the cruciate ligaments. Articular cartilage is then shaved tangentially with either a sharp osteotome or a sharp knife. This is done to eliminate fibrillated cartilage and cartilage pleats. The semilunar cartilages, if loose and degenerated, are removed.

If there are large lateral projections on the patella, and the patella is quite dense, this structure is removed in its entirety. Usually,

A B

FIG. 7. Preoperative roentgenogram (A) in a case of early degenerative arthritis of the hip two years following single severe trauma. B, the immediate postoperative film, showing removal of the supra-acetabular osteophyte without dislocation of the femoral head.

FIG. 7. C, a film made two years following operation. This patient was fully relieved from symptoms and had a normal range of hip joint motion. Prior to operation rotation was limited 50 per cent and the patient had only 10 degrees' abduction.

however, the patella is merely thickened, the cartilage degenerated on its posterior surface, and the posterior surface of the patella marked by other irregularities. A wide broad osteotome is used to divide the patella in a vertical direction into a posterior two-thirds or three-fourths, allowing the anterior remnant to remain in its attachment. After the posterior surface of the remnant is smoothed, a fat flap is cut from the infrapatellar fat pad, as shown in the illustration, and stitched into place with interrupted stitches. The treatment of the patella is facilitated by turning the posterior surface of the patella face-upward. This can be accomplished by grasping the medial surface of the patella with towel clips and everting it laterally over the finger or some other fixed structure. The patella is then inverted into the joint. The wound is closed by repairing the quadriceps expansion and the vastus medialis, preferably by interrupted non-absorable stitches.

The postoperative care is immobilization in a lightly padded or skin-tight plaster cylinder for three to five days. When the cylinder is removed 2, 3, or 4 inch cotton elastic bandages are used to support the knee for the next week. Weight-bearing is begun on the second or third postoperative day, and the patient is out of bed in the wheel chair on the day following operation. The joint is near normal, and the patient returns to work in six to twelve weeks. Slow

A B

Fig. 8. A, preoperative and B and C, postoperative roentgenograms taken of a forty-six year old man whose hip was the seat of an extensive degenerative arthritis of unknown etiology and of twelve years' standing. Although not well shown in the preoperative film, the hip was the seat of one of the most extensive and intricate interlocking systems of osteophytes on both femoral head and acetabulum. The only change in the femoral head was subchondral sclerosis in the weight-bearing sector, as shown in C, after most of the osteophytes had been removed at a two-stage approach, one anterior and the other posterior. B, made after the anterior stage had been performed with removal of an estimated two-thirds of the total bulk of osteophytes.

improvement takes place for a year or more following operation. Any type of modern anesthesia is used with a preference for continuous or single spinal or some type of gas anesthesia.

Results from Joint Mobilizing Operations on the Knee. The results on thirty-seven cases are summarized below. The minimum follow-up period was two years, and the longest period of observation was eight years. The cases are grouped as follows:

A: Four cases in which patellaplasty only was performed. These were cases in relatively young persons who exhibited continued pain following a single trauma to the knee without fracture. The diagnosis was post-traumatic chondrodystrophy of the patella. Each of these patients had a normally functioning knee without pain and a full range of motion within four months following operation. The maximum follow-up period in these cases has varied from two to six years.

B: Patellaplasty with more or less complete joint débridement. No cases of bilateral

Fig. 8. C, made six months following the second stage. The patient was almost fully relieved of pain and motion was increased at the hip from 30 to 80 degrees flexion and rotation and abduction from nil to 50 per cent of normal. Interposition substance was not used because at operation the cartilage on the femoral head appeared of good thickness when viewed by manipulating the hip without dislocating it.

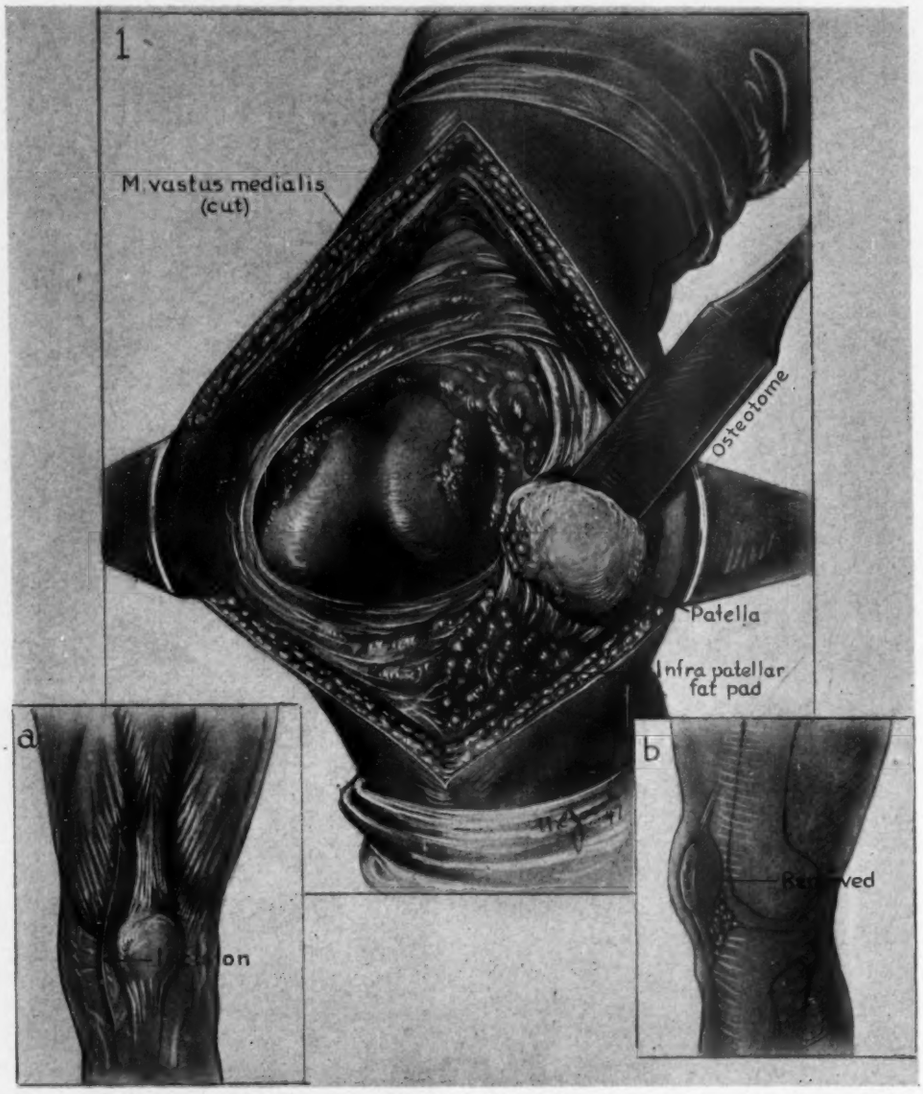


FIG. 9. Half tone drawing showing, *a*, the incision and *b*, the approximate amount of the posterior patella removed in the modification of the Magnuson joint débridement operation used in the cases herein reported. The main drawing, 1, shows the method of sectioning the patella vertically with a broad osteotome.

degenerative arthritis or of degenerative arthritis occurring in obese women are included. Thirty-three cases in this group were subdivided as follows:

1. Single major traumatic history followed by continued pain but without discernible fracture, twelve cases.
2. Old fractures of the tibial and femoral condyles with original good reductions but with continued pain, four cases.
3. Degenerative arthritis of the knee of unknown causation, seventeen cases.

The results were good in thirty-one of the thirty-three cases in this group. The standard of a good result was at least 130 degrees of active and passive motion and the presence of no or minimal pain. The results in the majority of these cases would be classed as spectacular with practically complete relief after months and years of chronic disability. The results were rated as fair in two cases. Both of these patients presented marked diffuse cartilage destruction throughout the joint and continued to have a certain amount of pain following operation. There was marked restriction in motion in these joints, the end results being only 30 degrees of active motion in one case and two-thirds of a normal range of motion in the other case. The

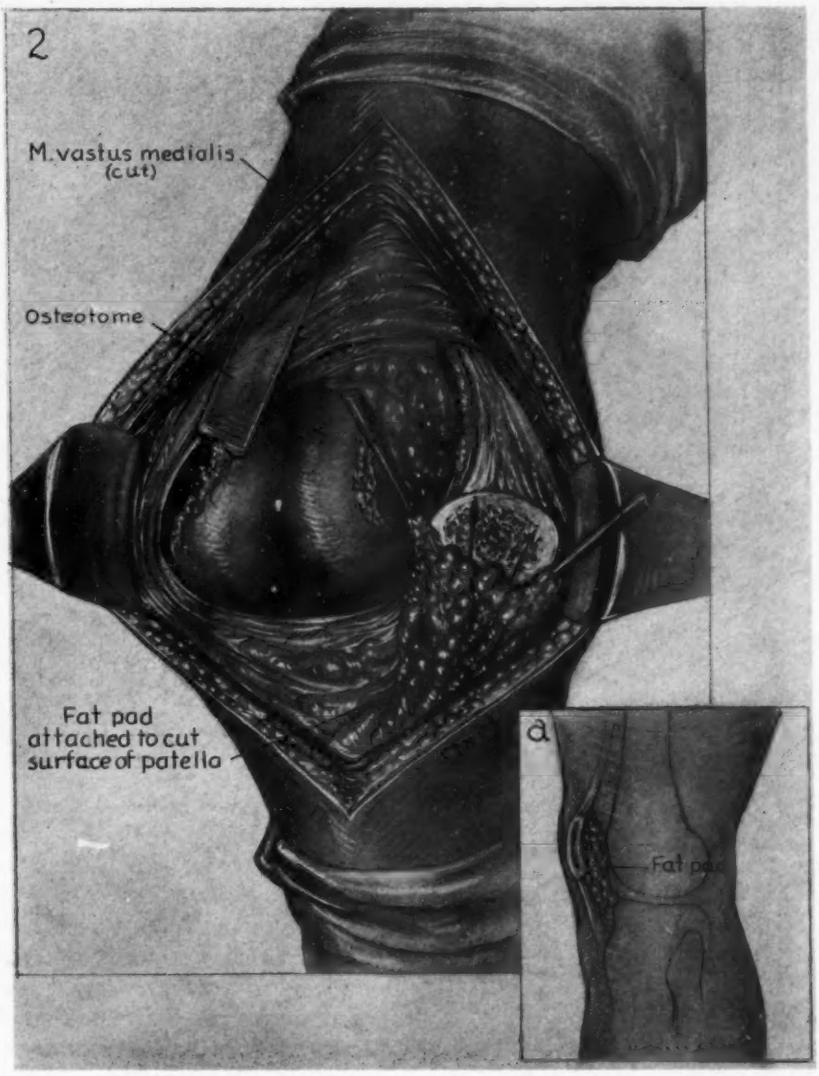


FIG. 10. Half tone drawing showing, *a*, the position of the sectioned infrapatellar fat pad as used to cover the posterior patellar surface. 2, the main drawing, shows removal of the marginal osteophytes on the femoral condyle by tangential trimming with an osteotome and the application of the fat graft to cover the raw posterior patellar surface.

chief results achieved in these two cases were relief from pain and soft tissue swelling around the joint.

THE SHOULDER

Two groups of cases of degenerative arthritis of the shoulder joint were operated upon. Cases that warrant operative procedure on the bony components of the shoulder joint aiming at motion are not frequently met, as the majority of cases of trauma to the shoulder result in injury to the soft tissue structures. The six cases reported here are divided into two groups:

A: Two cases of ancient marginal fractures of the humeral head with extreme deformity of the humeral head, degenerative arthritis of the glenoid and lack of motion as a result of interlocking between humeral head osteophytes and the glenoid (Fig. 12.)

B: Four cases of minimal degenerative arthritis of the glenoid face with production of posterior marginal osteophytes. These were all occupational in origin occurring in glass blowers.

Operative Technic. The most universally applicable approach to the shoulder for exploration and operation on the glenoid is by the

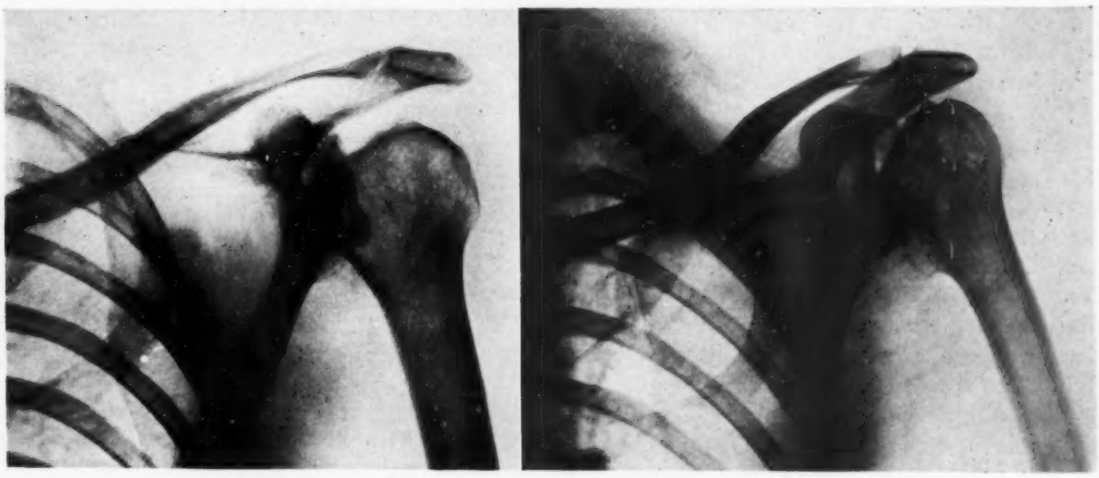
A B

FIG. 11. A and B, preoperative views of a knee, the seat of degenerative arthritis twenty years after a pyogenic joint infection in adolescence. The operation consisted of excision of the posterior two-thirds of the patella and smoothing of the condylar surfaces, both marginal and articular. The patient was fully relieved of pain, and postoperative active motion of the joint was 50 per cent greater, due to abolition of muscle spasm. The final range of motion was 75 degrees from 175 degrees.

FIG. 11. C, lateral postoperative view of knee.

posterior route. The origin of the fibers of the posterior third of the deltoid are stripped from the scapular spine and reflected outward. The tendinous portion of the infraspinatus and teres minor is incised, and the joint capsule stripped from the posterior margin of the glenoid, when it is desired to remove osteophytes from this region. If there are no posterior glenoidal osteophytes, and it is desired to operate on the femoral head or inspect the interior of the joint, the capsule is opened by a vertical incision. In the two cases of ancient marginal fracture of the humeral head with gross deformity of this structure, the several spheres of curvature of the humeral head were reduced into a single smaller curved structure. Care is taken not to resect bone below the anatomic neck of the humerus. The attachment of the musculotendinous cuff is left intact. (Fig. 12.)

Results. The period of observation in the two cases in which partial resection of the humeral head was performed have been eight months in one case and four years in another. In one case, 110 degrees of active abduction of



A B

FIG. 12. A and B, the preoperative anteroposterior views of a shoulder, the seat of extensive degenerative arthritis complication marginal glenoid and marginal humeral head fractures. These views were made four years after the fracture occurred. A, an anteroposterior view in neutral; B, an anteroposterior view in extreme internal rotation. Note that there are three centers of curvature for the deformed humeral head. These osseous ridges interlocked with the posterior-inferior glenoidal osteophyte, resulting in almost complete elimination of shoulder joint motion accompanied by pain and weakness of grasp when attempting to abduct.

humerus on glenoid were secured, and in the other case, 80 degrees. Thirty-five degrees of external rotation was obtained in one case, and 90 degrees in the other. The functional results in both cases were excellent and there was no pain.

In the four cases in which resection of posterior glenoid rim osteophytes was performed in glass blowers, a normal range of motion without pain was secured in three cases and a near normal range of motion in a fourth case, but with a certain amount of continued pain. Three of these four latter cases returned to work in eight weeks. The fourth patient changed his occupation. The period of observation was one year in two cases and three years in two others.

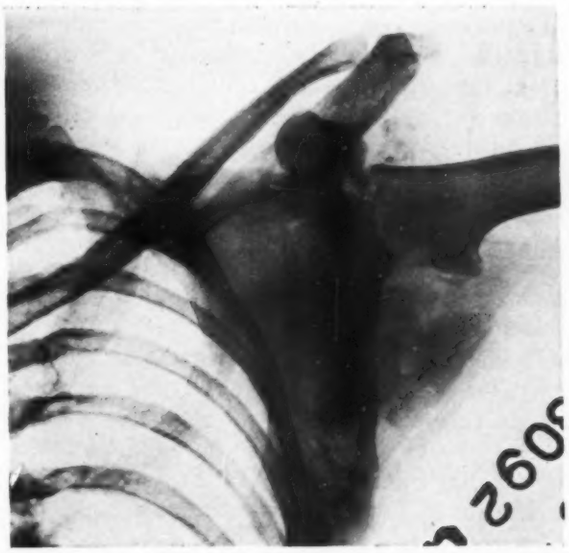


FIG. 12. C, the postoperative view demonstrating maximum passive abduction, which was approximately 90 degrees.

SUMMARY AND CONCLUSIONS

Long term follow-up instances of operations performed for increasing motion and improving the mechanical conditions in joints are presented. The majority of these patients exhibited post-traumatic degenerative arthritis.

Arthroplasty with plastic cups on single damaged hips exhibiting degenerative arthritis or aseptic necrosis of the femoral head, evaluated five to seven years after operation, showed 61.1 per cent good results and 22.2 per cent poor results. A detailed study of roentgenograms in these cases revealed further aseptic change or wearing away of the head in most of the cases rated as fair or poor. The complication of fracture of the acrylic cup was observed in two instances in these restricted etiological groups. As a result of these observations, the operative technic has been changed in the direction of major operative attack on the acetabulum with minimal operating on the femoral head consistent with removing marginal osteophytes and securing a mechanically sound hip joint with loose fit of the femoral

head within the cup and the cup within the acetabulum. An improved plastic cup, 3/16 inch in thickness and manufactured from a solid block of harder acrylic resin is now used. In the few cases in which an extremely thin interpositional material is required, Vitallium cups are used. These latter cases are those requiring little removal of bone and cartilage in securing a mechanically sound joint.

The results from arthroplasty on the hip in unilateral degenerative joints, all post-traumatic in origin, in which the slightly thicker plastic cups have been used and in which the primary operative attack is on the acetabulum, show 87 per cent good results. The evaluation was made one and one-half to three years following operation. The criterion of a "good" result is increase in motion, complete or nearly complete elimination of pain and a satisfactory result for the patient requiring no auxiliary support such as canes.

Exostectomy on the femoral head and acetabulum without using interpositional material is a palliative operation which may be indicated as a preliminary to arthroplasty or subsequent joint fusion. Eighty per cent can be expected to be improved for a variable period of time. The three-year and longer term results from this operation are not as favorable as those from the improved technic for cup arthroplasty.

Partial patellaplasty for post-traumatic chondrodystrophy of the patella has yielded excellent results with normal functioning knees in four cases. Patellaplasty combined with joint débridement gave good results in thirty-one of thirty-three cases (93.9 per cent) of unilateral degenerative arthritis of the knee joint. Half of these cases had a major traumatic history with or without fracture.

Improved function and elimination of pain occurred in two cases in which a partial resection of the humeral head was done in cases of post-traumatic arthritis following humeral head fractures in which the restriction in motion was due to interlocking of osteophytes and other osseous and cartilaginous mechanical difficulties within the joint. Full improvement occurred in three of four cases of glass blowers' shoulder, a condition characterized by posterior glenoidal osteophytes.

None of these procedures should be carried out on hips, knees or shoulders in which cartilage degeneration is nearly complete, as arthrodesis of the joint will give a more satisfactory result for those patients who must depend on the extremity.

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DISCUSSION

Kellogg Speed (Chicago, Ill.): Perhaps you will agree with me that this is rather a difficult paper to discuss in its range of subject.

Dr. Harmon's treatment of this extensive series of limited and painful motion in various joints following trauma aims to gain increased functional

results by various means for varying causes. Surgical efforts are induced to dissipate the patient's distress and to return such functional range of motion in the given joint so that re-employment may follow.

My experience coincides with some of the points he enumerates. It is remarkable how much improvement may be returned after rather simple excision of blocking or confining bone-cartilage restriction about or in a joint, followed by controlled active and passive motion and perseverance on the part of surgeon and patient.

Whether arthroplasy with an intervening foreign body is required in any case calls for experienced surgical judgment. Its best use seems to be in the weight-bearing joints. In my experience, arthroplasty for pure or long standing osteoarthritis often results in final recurrence of pain, stiffening and failure, the disease being systemic with unrecognized extension of the local process. Often in pure traumatic or mild infectious arthritis which is local, excluding tuberculosis, results are acceptable and lasting. In the hip, not enough attention is paid to free excavation of the acetabulum and less whittling down of the head of the femur, as he has brought out, but I believe that it is more important to preserve the integrity of the "Y" ligament of the hip rather than to attempt to save the fibrous capsule of the joint which has rapidly regenerating powers.

Of all the joints, the elbow gives the least satisfactory result on anatomical grounds alone. The small joints of the finger respond well to delicate treatment. Selection of material for surgically formed new joint coverage or protection is a matter of choice by the surgeon. More depends on the delicate yet extensive restoration of freedom of joint motion and removal of all blocking mechanical hindrance than on the material used to cover raw bony surfaces. Fascia lata with a fat layer is always available. The postoperative muscle training and restoration of the patient's morale become major points in the follow-up.

These procedures involve complicated and custom made surgery to fit each case. They lead to lessened disability and decreased economic loss. If failures arise purely on the basis of changed or decreased blood supply, an attempt to increase this supply locally by using transplanted pedicled muscle flaps into the bone, as suggested by Stuck and Hinchey, may, after further trial, be found to be of definite and lasting value. This is doubtful, however, as the implanted muscle, losing its normal function, atrophies rapidly, thus losing vascularity.

I would like to say, in the case of the knee, I have done a few of these by shaving off the patella and putting fat over them and going back in nearly every instance within a year and finally removing the patella, much to the patient's advantage.

PERIOSTEUM FOR REPAIR OF FASCIAL DEFECTS IN THE PARATIBIAL REGION OF THE LEG

RESULT OF ITS TRANSPOSITION

NICHOLAS J. GIANNESTRAS, M.D.
Cincinnati, Ohio

LERICHE and Policard in their excellent book on bone physiology and pathology state: "The periosteum is the fibrous membrane which surrounds bones and separates them from the environing tissue: it is nothing more."[1]

With this statement in mind the following procedure was developed for repair of fascial defects which occur along the lateral margin of the shaft of the tibia. An investigation of the literature does not reveal any previous report of the use of this method. The author wishes to present two cases repaired by the use of this procedure and by the end result achieved further strengthen the stand taken by Leriche, Policard, MacEwen, Goodsir, Murray and others that the periosteum in the adult is only a limiting membrane and has no osteogenic function *per se*.

CASE 1. (Mr. H. C. K.) The patient was seen on January 26, 1946, complaining of pain and swelling on the anterior aspect of the right leg just lateral to the edge of the tibia in the mid-portion. He stated that this mass had been present for the past two or three months and had been getting progressively larger. The patient suffered a compound fracture of the lower third of his right tibia while in combat and had been hospitalized for a period of approximately six months. He first noticed the presence of a very small painless mass in the lateral paratibial region at the level of the fracture site when the cast was removed, and this mass was still present when the patient was discharged from the service. However, because of no discomfort over this mass and over the surrounding area, the patient did not complain about it. Since his return to work as a truck driver, he had pain not only over the fracture site, but over the previously described mass, particularly after a day's work or any excessive walking. He had noticed that with changes in weather he experienced aggravation of the pain at the fracture site. The mass was not located at the fracture site but little higher up on the leg. The patient had observed that it was increasing in size and in symptomatology.

Examination revealed a well developed, well nourished, twenty-three year old white male, who walked into the office with a slight limp of his right lower extremity.

Examination of the right leg revealed the presence of a mass on the anterolateral aspect of the leg at the mid-portion just lateral to the edge of the tibia. This mass was 1 inch in width, at its widest portion, and approximately 3 inches in length. There was definite tenderness present upon pressure, and the underlying muscle belly could be easily palpated and delineated when the patient stood up. The edge of the fascia could also be palpated. At rest the mass reduced somewhat in size, but the tenderness was still present. A diagnosis of muscle hernia on the anterior aspect of the right leg at the junction of the upper and lower halves of the shaft of the tibia was made.

The patient was advised that surgery was the only therapy which could be prescribed in this instance. He was told that an attempt would be made to repair the hernia if this was at all possible. However, if this were impossible, the fascia would be split along the entire length of the leg thus releasing the tension along the fascial edge.

On February 13, 1946, repair of the hernia was performed under general anesthesia with the use of a tourniquet. The operative procedure was as follows:

A 7-inch curved incision was made on the lateral aspect of the leg beginning just below the level of the tibial tubercle and extending distally. A definite defect of the fascia was found at the level of the mid-shaft of the tibia. This defect permitted protrusion of the underlying musculature through the opening. In addition to this, however, there was marked thinning of the fascia proximally and distally for a distance of 4½ inches. The fascia was detached from the tibia and the defect was at least 1¼ inches wide. An attempt was made to reattach the fascia to the periosteum, but this was impossible. Accordingly, therefore, an incision was made on the periosteum at its medial edge for a distance of at least 6 inches. A flap of the periosteum was then developed following which this structure was lifted, by the use of a blunt periosteal elevator, from the anteromedial surface of the tibia and attached to the fascia along its entire length. The defect was thus closed over

with interrupted No. 60 white cotton sutures. At the end of the closure there was separation of the muscle mass from the lateral tibial surface since the periosteum was pulled over to the fascial edge, but the defect was entirely closed. The skin was closed with interrupted No. 60 white cotton sutures, and a long leg cast was applied extending from the toes to the mid-thigh with the ankle at 90 degrees dorsiflexion and the knee at 15 degrees flexion.

The cast was removed at the end of a six weeks' period. During this time the patient was not permitted to bear any weight on the involved extremity. Following removal of the cast, active weight bearing was permitted, and the patient was allowed to return to work as a truck driver at the end of ten weeks.

The patient has been seen on several occasions since then, the last occasion being on April 12, 1947, at which time a biopsy of the leg was performed under local anesthesia. A 1½ inch incision was made just along the lateral tibial edge in the region of the mid-shaft of the tibia, and a specimen of tissue was removed from the area of the fascial defect, as well as another specimen from the surface of the tibia. The area of the herniation appeared to be well healed and there was no evidence at this time of any thinning of the overlying tissues. In regard to the tibia itself a new layer of fibrous tissue, or rather a new layer of tissue, covered the anteromedial surface of the tibial shaft, and this tissue was well adherent to the bone. Microscopic sections of both specimens were made.

Case II. Mr. H. B. was a twenty-four year old, white male, who stated that approximately three years ago, while in the service, he was involved in a plane crash at which time he suffered a simple fracture of his left tibia. Accordingly, he was hospitalized at that time and his leg was immobilized in a cast. Active weight-bearing was begun at the end of three months when the cast was removed. He began to have pain over the fracture region and just a little lateral to it, and he was finally discharged from the service because of his disability.

Because of continued symptomatology he reported to the Veterans Hospital in Dayton, Ohio, in October, 1944. At this installation a diagnosis of muscle hernia of the mid-paratibial region of the left leg was made, and this was repaired by using fascia from the opposite thigh. For approximately a year following this the patient had no sympotomatology whatever. On October 14, 1945, he was involved in another plane crash, and in preparing and bracing himself for the crash when he landed, the patient felt a sudden searing pain in his leg and noticed the reappearance of the hernia within twenty-four hours.

Since that time the patient had been having a great deal of disability with the left lower extremity and he was finally seen at the office complaining of aching along the anterior mid-portion of the leg whenever he walked for any length of time or performed any strenuous work. Damp weather seemed to aggravate the situation a great deal. He further stated that he noticed his toes tended to drag a little whenever the leg was tired. When first arising in the morning, the leg was somewhat stiff and painful, but not as severe as it was after a day's work.

Fig. 1. There is no evidence of any bone formation where the periosteum covers the muscle hernia.

Examination revealed a well developed, well nourished, white male, who walked into the office in no apparent discomfort.

Examination of the left lower extremity was essentially negative, except for the left leg. A 4-inch scar was present on the anterolateral aspect of the leg just lateral to the tibial edge at the mid-portion. The scar and the surrounding tissue, particularly at the edge of the tibia, were quite tender to touch. Upon standing there was a definite herniation present of the muscle bellies of the extensor digitorum longus. The mass which was palpable was 5 inches in length and approximately 1½ inches in width.

A diagnosis of muscle hernia of the leg due to rupture of the fascia overlying the musculature in the middle paratibial region of the left leg was made.

The patient was advised that the recommended form of therapy here would be another repair of the herniation. Accordingly, on June 24, 1946, the patient was hospitalized and on the following day operative repair of the muscle hernia was carried out.

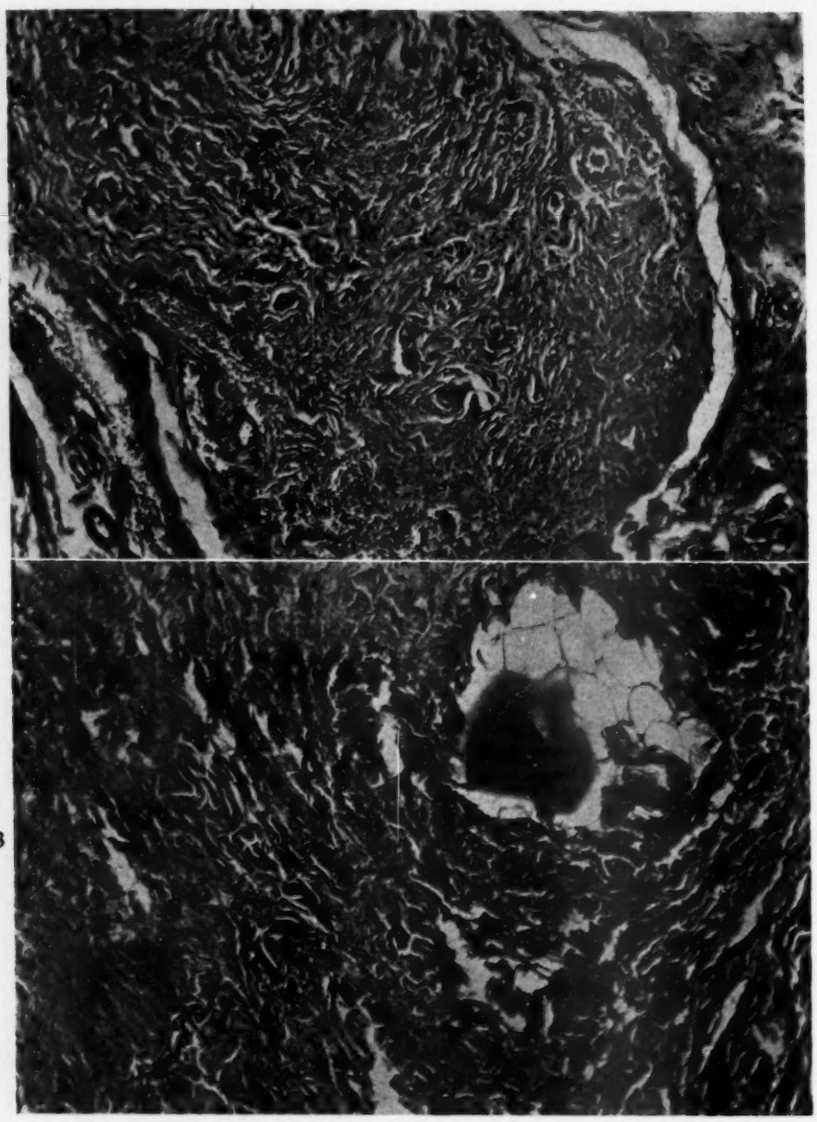

FIG. 2. Section of transplant. Microscopic section reveals the tissue to consist chiefly of collagen as verified by the trichrome stain. Several areas of fibroblastic proliferation are seen accompanied by some multinucleated cells suggestive of foreign body reaction.

FIG. 3. Section of new tissue covering bone. Tissue composed of fat on one surface while the other border reveals collagenous material with flecks of calcium. The collagen is relatively acellular.

At operation it was found that the fascia was torn from its tibial edge on the lateral aspect of the tibia for a distance of approximately 7 inches extending from the junction of the upper and middle thirds of the tibia distally. The width of the hernia was between 3 to 4 inches at its widest portion. A 12-inch incision was made along the lateral edge of the tibia. The old scar was excised, following which the skin was reflected laterally exposing the entire muscle hernia. The edge of the fascia was identified and was freed on the lateral aspect of the leg. Following this the periosteum of the tibia was incised along its medial edge from the level of the tibial tubercle and extended distally to 3 inches above the ankle joint. Transverse incisions were made at each end thus permitting lifting of the periosteum of the tibia with a blunt periosteal elevator. Following this the periosteum was stripped from the lateral surface of the tibia as well to permit approximation of the periosteum to the fascial edge. Upon approximation these two structures were sutured together in an overlapping fashion with interrupted No. 60 white cotton mattress sutures. The skin was also closed with

interrupted No. 60 white cotton sutures. A long leg cast was applied from the mid-thigh to the toes with the knee at complete extension and the foot at 90 degrees dorsiflexion. The cast was kept on for a period of six weeks, and upon removal of the same active weight-bearing was permitted.

The patient has been seen on repeated occasions since this time, and has come along quite satisfactorily. On February 17, 1947, the patient came into the office complaining of some pain over the region of the herniation and stated that the day before he had slipped and fallen and was afraid that he might have injured the operated area. Examination did not reveal any recurrence of the hernia.

The patient was last seen on March 29, 1947, at which time biopsy of the operative site was carried out under local anesthesia, and specimens were removed both from the transposed periosteum and the tissue which was present on the anterior tibial surface.

In Case I it 's now fourteen months since the operation was performed. The patient states that his condition is vastly improved. He is able to work every day at his occupation as truck driver, and except for some pain at the end of a day's work over the operative site and a feeling of fullness in his leg, he has no complaints whatever.

Roentgenograms taken recently (Fig. 1) reveal no evidence of bone formation where the periosteum covers the muscle hernia. Microscopic sections of this structure (Fig. 2) taken on April 12, 1947, revealed that the tissue consisted chiefly of collagen as verified by trichrome stain. Several areas of fibroblastic proliferation were present, accompanied by some multinucleated cells suggestive of foreign-body reaction. No tubercles were noted, though the area appeared granulomatous. Microscopic sections of the new layer of tissue covering the tibia from the area from which the periosteum was removed previously (Fig. 3) revealed that this tissue was composed of fat on one surface, while the other border was collagenous with flecks of calcium. The collagen was relatively acellular.

In Case II it is now ten months since operation. This patient is at the present writing waiting until June 1st of this year before reporting to St. Louis Browns as a pitcher. He has absolutely no symptomatology in reference to his leg. He is able to carry on with no difficulty whatever. His x-rays (Fig. 4) also reveal no aberant bone tissue, and the microscopic examination (Fig. 5) of the periosteal graft covering the fascial defect revealed that the tissue consisted chiefly of dense collagen which bore numerous small blood vessels. Diagnosis of dense collagenous tissue bearing numerous new blood vessles was made. Microscopic examination of the tissue covering the tibia (Fig. 6) revealed that approximately one-half of the section consisted of

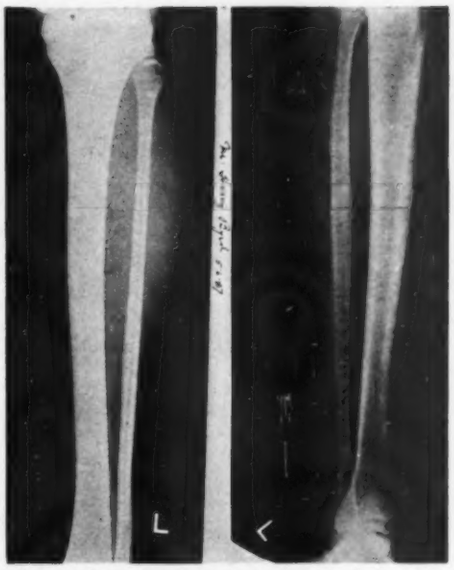

Fig. 4. No aberrant bone tissue is visible by x-ray in the area of the transplant of the periosteum over the hernia in the soft tissues.

adipose tissue, while the other half was made up chiefly of dense collagenous tissue. Much of the latter tissue was infiltrated with numerous red blood cells and a scattering of lymphocytes and polymorphonuclear cells. The entire tissue was fairly vascular. No evidence of new bone or calcification was seen. Diagnosis of vascular collagenous tissue bearing hemorrhage was made.

Thus we have two cases in which the periosteum, detached on three sides and permitting maintenance of circulation along the entire length of the graft from its attached side, did not produce any bone.

The main result from this operation is the fact that in each patient the defect was corrected without the necessity of "robbing Peter to pay Paul" by taking a fascial graft from the thigh. Of course, as one of my confreres suggested, Why not split the fascia along the entire length of the tibia and thus relax the fascial edge? In the first patient this procedure might have been successful since the fascial defect involved only approximately three-fifths of the length of the shaft of the tibia, but in the second patient the defect already extended from approximately just below the level of the tibial tubercle to 3 inches above the ankle joint, and the leg was still symptomatic.

The second conclusion to be derived from this procedure is that there are presented here two proved human cases in which periosteum, not

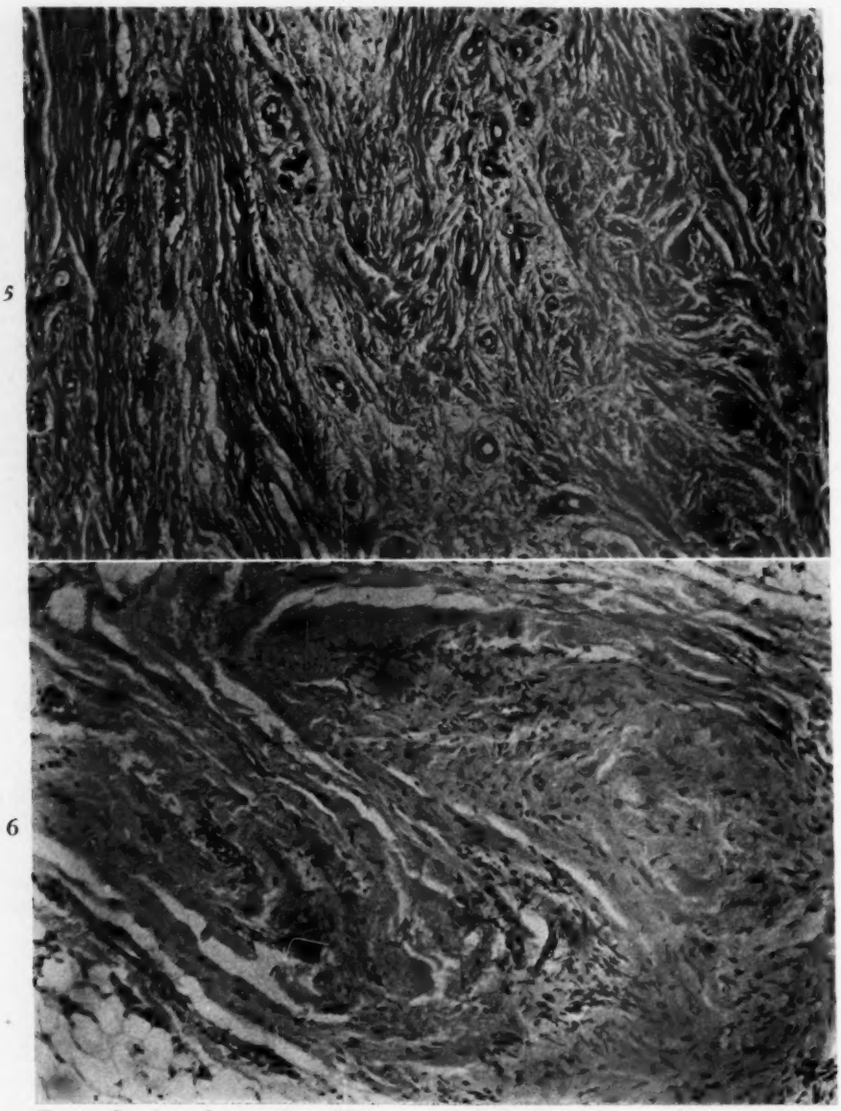

FIG. 5. Section of transplant. Tissue consists chiefly of dense collagenous fibers and collagen with numerous small blood vessels.

FIG. 6. Section of new tissue covering bone. Approximately one-half of this section consists of adipose tissue. The other half is made up chiefly of dense collagenous tissue which is infiltrated with numerous blood cells and a scattering of lymphocytes and polymorphonuclear cells. The entire tissue is fairly vascular. There is no evidence of any bone formation or calcification.

completely detached and, therefore, having a relatively good circulation, did not go on to bone production. Sir William MacEwen[2] basing his conclusions on thirty-two animal experiments and his long surgical experience held that periosteum, whether *in situ* or in transplant, has no osteogenic function. The bone growth results solely from bone cell activity. The periosteum acts only as a limiting membrane to the osteoblasts issuing from the interior of the bone. Blaisdel and Cowan[3] reported as follows: "The periosteum of the bones of young growing animals is quite thick, vascular, elastic and abundantly supplied with osteoblasts on its inner layer. If we compare this with the periosteum of an adult animal, one that has attained its growth, we find that this periosteum is relatively less thick, less vascular and elastic and that the osteoblasts are either flattened against the cortical surface as a single layer, visible at intervals, or very difficult to recognize or even absent." Murray,[4] in his numerous articles on the physiology of bone and bone healing, contends that the periosteum

is a limiting membrane and has no reparative function.

How then can these above statements be reconciled with Mayer's and Wehner's experiments[5] who, in carrying out their study of bone osteogenesis, came to the conclusion that the "transplants of the periosteum, subperiosteal resections, and bone transplants combine to emphasize the osteogenetic function of the specific osteoblastic cells of the periosteum and the inability of the adult bone cells to form new osseous growth."

This contention is also borne out by the excellent work of Urist and Johnson[6] who state that the intermembranous bone formation arises between the periosteum and the shaft by the proliferation of spindle-shaped cells in the inner periosteum which resemble fibroblasts which are termed "resting osteoblasts."

The author cannot and will not be so presumptuous, on the basis of two cases and the reading of many articles, to attempt to credit or discredit either school of thought, for the exponents of each school have performed a great deal of experimental work on a very controversial subject. The only conclusions which can be derived from these two cases are that: (1) An operative procedure is presented in which periosteum in the adult human can be used to bridge fascial defects in the paratibial region of the leg with good results; (2) that in *neither* instance was any bone developed by the transposed periosteum as evidenced by the roentgenograms and the biopsy studies, in spite of the voluminous literature to the effect that periosteum begets bone; and (3) that a new layer of fibrous tissue, definitely as adherent to the tibia as the periosteum had been previously, and resembling the previous periosteal layer was found to cover the outer cortex of the tibia.

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DISCUSSION

Laurie H. McKim (Montreal, Canada): I wish to thank Dr. Giannestras for the privilege of opening the discussion on this very interesting paper. I believe there will be other speakers who will review some of the controversial points which he has brought up.

I wish to take up only two aspects of this subject. I have noted that the cases that are reported by Dr. Giannestras are both the result of fractures of the leg. The cases that the majority of us saw in the Army were not the result of trauma, but were due to a congenital opening in the fascia. They were small in size, although some of them were as much as 2 inches in a vertical direction. Frequently, they were the site of a communicating vein between the superficial and the deep venous systems.

The majority of such patients were completely relieved of their complaints of pain or disability by the simple ligation of this communicating vein or sometimes even by the injection of some sclerosing material in the vein. Certain others were relieved by the procedure that Dr. Giannestras has spoken of, splitting of the fascia in a vertical direction, sometimes slightly in the lateral direction.

I would just like to call to mind the experience of many of us when we used to use fascia lata from the thigh for the repair of hernia, when we used to make a huge opening in the thigh and very carefully tried to close the fascia. The sutures did not hold and, of course, we got small muscle hernias through the openings in this long incision in the fascia and the patient complained of pain. In the course of time, the majority of us learned that it did not matter whether or not you closed these openings in the fascia; and with the introduction of the fascia stripper, you could not close them. Since the introduction of the fascia stripper, we have had very few complaints of pain.

Now, all of this is just to bring up the question as to what disability if any, the members of this Society believe these small hernias produce. How much disability have those men actually got?

The second point that I wish to discuss is the function, if any, of the periosteum as a bone-forming membrane. Dr. Giannestras has referred to the work of Leriche and Policard, which was published about 1926, as I remember it. About 1931, Gregg, of Edinburgh, published a very interesting book on the pathology of bone, and in that book he made this statement: "The osteogenetic ability of the periosteum remains unproved, and its non-partici-

pation as a bone-forming membrane is now widely accepted."

The work of Dr. Giannestras would seem to have added one more nail in the coffin of the ancient theory that the periosteum had very much to do as a bone-forming membrane.

I just wonder whether any member of this Society really thinks that there is any such thing as a true osteoblast. Does any member actually think that there is such a thing as a cell that is capable of producing bone under any conditions of growth, whether in transplant or otherwise? You will observe that I have used the words "true osteoblast."

Frederic W. Bancroft (New York, N.Y.): About 1915, antedating Dr. Murray's work, I did a good deal of work on experimental bone formation and functions of the osteoblasts and of the periosteum. The main experiment, which I think showed a good many of the factors involved, was taking a piece out of the radius in dogs, chopping it into small fragments and removing the periosteum and replacing the bone fragments. The more one studied the microscopical repair of bone, the more one came to the realization that there was no such thing as an osteoblast.

In the repair, blood vessels come in and there is granulation tissue with fibroblasts. Now, around these fibroblasts, one begins to see bone reaction; but if one goes to the borderline of this bone reaction, one finds a gradual transition between the so-called osteoblast and the fibroblast, and I defy anybody to say which is fibroblast and which is osteoblast. As they come into the deposition of calcium around the granulation tissue a perfectly regular repair is formed, blood vessels come in, an area of areolar tissue around the blood vessels occur, and calcium deposition and fibroblasts in this surrounding tissue appear.

One finds definite cartilage cells where there is motion. As one goes to transition between cartilage and fibroblast, one can say, "Here is a cartilage cell and there is a fibroblast," but then there is a transition area where one cannot differentiate. You can observe an intermediary zone and you and I might argue that one is a cartilage and the other, a fibroblast. Therefore, it is my impression that bone formation is the result of deposition of calcium salts on granulation tissue, where the cell is caught in and is not the cause of the process.

I think that is true with periosteum. We tried numerous places where one could transplant periosteum. If you transplant periosteum where there is a base rich in calcium, as in the bladder, you are apt to see bone formation. One can produce bone formation in the kidney by ligating its vessels and wrapping the omentum around it. Here one will find bone cells in the kidney itself. It is very hard to tell why. In the bladder, one may insert a fascia lata transplant and get true bone formation.

Why do osteoblasts wander into the fascia lata that one uses for transplants in the bladder? Why do osteoblasts wander into a kidney that has been deprived of its circulation and new circulation re-established?

The observer has to come to the conclusion that bone formation is a biochemical deposit of calcium on granulation tissue, and that the so-called fibroblast by metaplasia becomes an osteoblast.

Marshall R. Urist (Boston, Mass.): Dr. Giannestras, prior to the time of the reading of his paper, had informally challenged me to defend my thesis on the mechanism of osteogenesis in healing fractures reported in four papers in the *Journal of Bone and Joint Surgery* between 1941 and 1943. The point of disagreement between us, as I gather from his conclusions this morning, is the question of the function of the periosteum, a controversy in the literature nearly three hundred years old. Briefly our view was that new bone comes from pre-existing bone tissue in response to the stimulus of injury. This applied to the replacement of bone grafts as well as the healing of fractures. In healing fractures which is the condition to which I should limit my remarks, the new bone forms by differentiation of osteoblasts beginning between the cortex and the periosteum some distance from the fracture line. There is little doubt as to the identity of these cells or that they originate in the cambium layer of the periosteum. The reaction of the periosteum and this type of new bone formation also occurs not only with bone injury after trauma but also with infection or neoplasm.

This is not the time for a discourse on the histophysiology of the bone cell, even if I could answer, which I cannot, all the important questions which I have heard this morning. Rather I would refer you to the recent work of McLean and Bloom and the tissue culture studies of Heinen, whose writings have been communicated thus far mainly to nonclinical audiences, but to which I subscribe and believe will one day be extended closer to our clinical problems. In healing fractures, just as in other conditions, we find that whenever bone trabeculae form, a specific cell is also present which can be identified histologically as an osteoblast. Injured bone apparently has the effect of *inducing* the proliferation of osteoblasts connective tissue cells surrounding viable bone. In healing fractures the process is set off like a trigger mechanism and rapidly goes to the point of repair of the bone defect.

It is established from a great number of well known experimental works, that a graft of periosteum isolated from bone tissue gives little or no new bone formation. Our interpretation of this fact and the experiments of Dr. Giannestras, is that the periosteum does not demonstrate osteogenic potency without the stimulus of injured bone.

I would assume that the cambium layer, which has a blood supply of terminal penetrating capillaries, dies when it is stripped up or transplanted into soft parts. Presumably after this happened in Dr. Giannestras operation, and without the osteogenic stimulus from injured bone, the surviving periosteum failed to proliferate and produce osteoblasts or new bone.

The lack of osteogenic potency in the transplanted periosteum may be interpreted by Dr. Giannestras as evidence against the "osteoblastic theory" and as corroborative data for the "metaplasia theory" of Leriche and Policard, the writings of Murray and Stirling, the experiments presented yesterday by Hudack and the remarks this morning of Dr. Bancroft. We believe that our experiments show that new bone formation in healing fractures comes with the formation of osteoblasts which develop from the periosteum and the endosteum, rather than by metaplasia of connective tissue cells directly into bone by such factors as small variations in pH or local calcium ion concentration. To reconcile ourselves with the conclusions of Hudack, we would question the identity of matrix without bone cells. We wonder if the material which he finds between the filaments of lucite is old fibrin. Nearly everyone would agree with Dr. Bancroft that osteoblasts do not wander into the bladder. However, as clearly demonstrated by Huggins ectopic bone develops from osteoblasts *formed in connective tissues in contact* with transplanted urinary bladder epithelium. We know only very little about the osteogenic stimulus in urinary bladder epithelium, for that matter any of the conditions which produce extraskeletal bone formation, but new information appears to be coming into the scientific literature every day.

Boardman M. Bosworth (Bronxville, N.Y.): I simply want to digress a minute and ask Dr. Giannestras if, when he did his biopsies, he found any evidence of what happens to his No. 60 cotton.

Paul H. Harmon (Huntington, W. Va.): That there are cells whose sole function is the elaboration of the type of intercellular matrix which we know as bone, is shown by the fact that there are malignant tumors, whose metastasizing cells have the power to form a more or less typical intercellular matrix of bone. This line of evidence, of course, gives no clues concerning the normal morphogenesis of bone, but indicates that there is a type of cell sufficiently differentiated to form the typical malignant tumor, on occasion.

The common occurrence of bone in the urinary tract, especially in the bladder wall, is explained, in part, by the rich content of urinary tract epithelium in phosphatase. The property of urinary bladder epithelium to form bone when traumatized in the presence of foreign bodies, has been the contraindicating factor to the use of non-absorbable suture material for the repair of bladder wounds. When cotton or silk is so used, calcification and often ossification occurs about the sutures.

Harry E. Mock (Chicago, Ill.): I had the temerity in May, 1928 to publish a paper on pure periosteal transplants in ununited fractures. I cannot resist speaking here as a clinician. In my studies and experience, pure periosteal transplants placed about the site of an ununited fracture even with loss of bone substance between the fractured ends did result in union.

During those experiments on dogs, when we would transplant periosteum in the soft tissue where there was no function called for and where it did not belong, we never got bone. But when we put it about the bone and attached it to the bone, it did beget bone or, rather, it did stimulate the growth of bone and resulted in union.

Following the Frenchman's work—I cannot think of his name—and others, we have since attached small particles of cortex to the periosteum, thus giving a containing membrane with some bone material and this stimulated the growth of bone quicker. I do not think the fact that the essayist proved that his transplanted periosteum failed to beget bone out where bone was not intended to be proves that periosteum has no value in ununited fractures.

Nicholas J. Giannestras (closing): Gentlemen, my head is bloody but unbowed.

I would like to thank Dr. McKim for his discussion. I agree with him that in small muscle hernias, this type of surgery is definitely not indicated.

I asked Dr. Urist, rather than challenged him, to discuss the paper because I thought he certainly had something to contribute, and I am glad that he did come up to discuss this thing, because I admit that I do not know as much about bone physiology as he does, since he has done so much experimental work. But it was simply the fact that here was something to bring out a discussion, so that we could possibly get various ideas about the matter.

He brought out the fact that the cambium layer died in the periosteum and therefore did not beget bone. The one statement that I still cannot understand is how he comes to the conclusion and how Dr. Urist can differentiate a resting osteoblast from a fibroblast. Probably that may be splitting hairs but I have tried in my own way to find out how to differentiate between a fibroblast and an osteoblast in the normal periosteum when sections have been made of it, and I agree with Dr. Bancroft that it is a rather difficult thing to do.

As far as the cotton sutures go, Dr. Bosworth, they were still in there. They had not been absorbed.

PRACTICAL PROCEDURES FOR THE CORRECTION OF SCAR CONTRACTURES OF THE HAND*

PAUL W. GREELEY, M.D.
Chicago, Illinois

SCAR contractures of the hands and fingers commonly arise from spontaneous healing of deep second or third degree burns, from avulsions of skin, certain lacerated wounds, or poorly planned surgical incisions. The correction of the majority of lesions of this type is not ordinarily difficult, provided certain fundamental principles are kept in mind when planning the type of repair.

The hand is a highly kinetic organ and when deciding upon the procedure to use in correcting a scar contracture, a type of operation must be utilized that will not interfere with the normal hand and finger mechanism. It must be remembered that all scars tend to contract and that any incision or suture line that runs parallel to a flexor or extensor surface will in all likelihood result ultimately in a hypertrophic scar that will produce a contracture. Hence, all incisions, suture lines and skin graft edges must be calculated so that they will fall either transversely or obliquely across the longitudinal axis of the flexor or extensor surfaces of the hands and fingers. If this design is carried out and a postoperative shortening of the suture line should occur, the pull will loose its force in a lateral direction and therefore will not interfere with the normal flexion and extension mechanisms.

OPERATIVE PROCEDURES

Whenever possible, one should always utilize local tissues when reconstructing hand contractures if the skin loss has not been too great. Not only is the operation simpler but normal hand skin gives the best functional result. Skin grafts are a substitute to be used only when adequate tissue is not available for local use. Normal hand skin withstands daily trauma better and sensation is more nearly normal. Stereognosis can never be replaced by skin grafts from other areas since the special organs for this sensation are found only in the pacinian corpuscles located normally in the finger pulps. Consequently, when correcting linear contractures wherein there is sufficient available skin along the borders, a single or multiple Z-plasty will give the best result with minimum surgery. (Figs. 1, 2A and B.) The use of this procedure, however, is limited to the amount of available skin flap on either side of the wound after excision of the contracting scar. Larger defects, by necessity, must be covered with a carefully selected type of skin graft.

When the necessity for the use of a skin graft arises, some type of free graft, either full-thickness or split-thickness as indicated, must always be utilized when there is an adequate subcutaneous fat pad present that covers the underlying tendons, bones and joints. If this fat pad has been lost in the original injury or its subsequent complications, one must be prepared to cover the defect with a flap of skin to which a fat pad is attached.

It is the experience of plastic surgeons doing considerable amount of hand surgery, that the best functional results occur after replacement of the skin on flexor surfaces when free full-thickness or Wolfe grafts are employed. This type of graft will give the maximum degree of elasticity and the best surface bearing qualities. (Figs. 1, 3A, 3B, 4A, 4B, 5A, 5B).

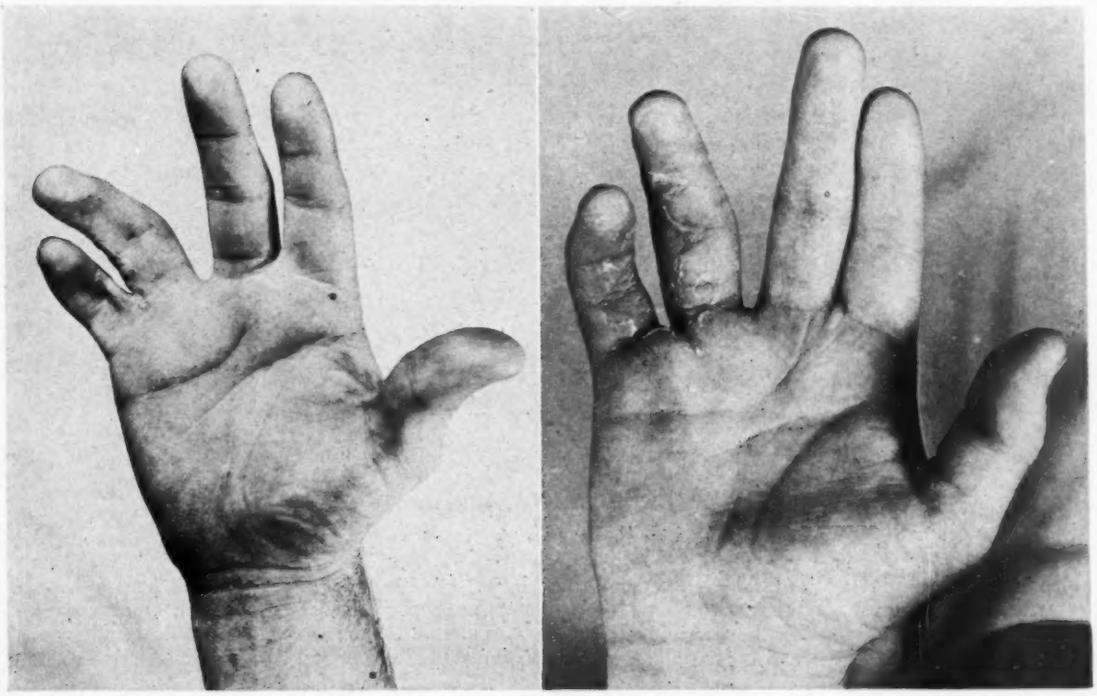
On the other hand, one may use thick split-thickness skin grafts on the extensor surfaces to great practical advantage. These grafts are simpler to cut and may grow and they will supply sufficient elasticity and surface bearing qualities to cover defects on the backs of the hands and fingers. While one could also use the free full-thickness graft in this location, the comparative simplicity associated with the split-thickness skin graft for extensor surface defects has made it almost a standardized procedure. (Figs. 6A and B.)

Again it should be pointed out that in using either of these types of free skin grafts, one must always avoid a straight suture line along the graft edge when this line runs parallel to

* From the Department of Surgery, Division of Plastic Surgery, University of Illinois College of Medicine, the University of Illinois Research and Educational Hospitals and St. Luke's Hospital, Chicago, Ill.

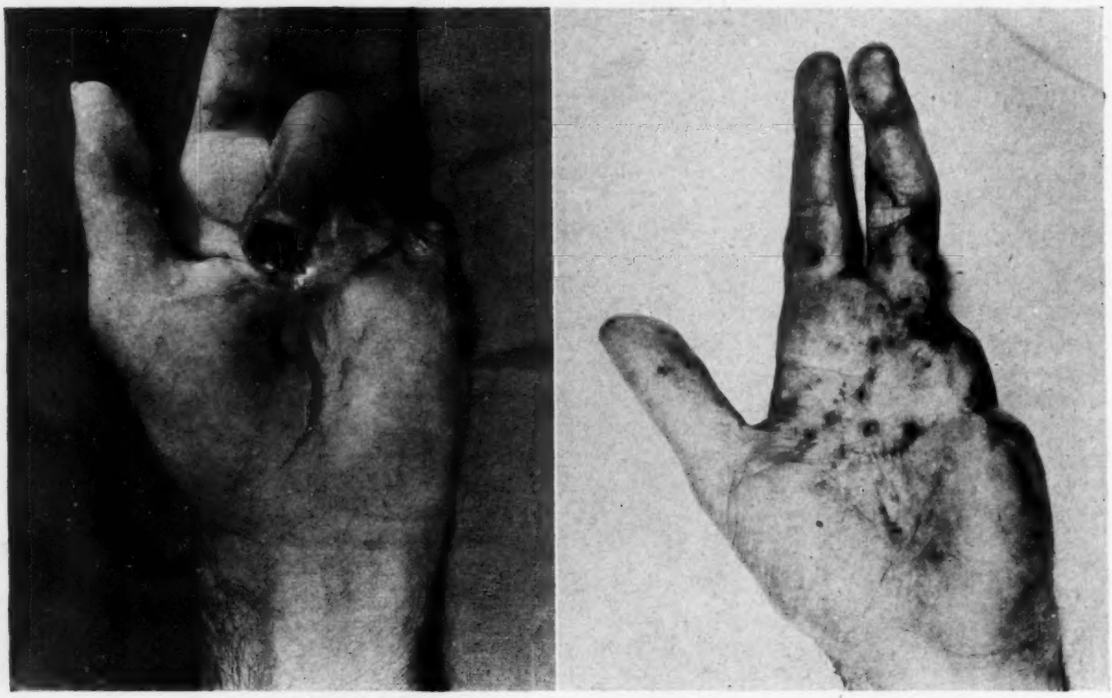
Scars excised. Z-plastic procedure elected where defect long & narrow with small loss of skin.
Wide defects trimmed to diamond shape
Free full-thickness grafts applied to wide defects; z-plastic flaps being rotated.
All suture lines diagonal to axis minimizing contracture by scars.

FIG. 1. Showing points of importance in correction of flexion scar contractures of the fingers. Note creation of staggered suture lines. Z-plasties preferable when adequate border skin is available.



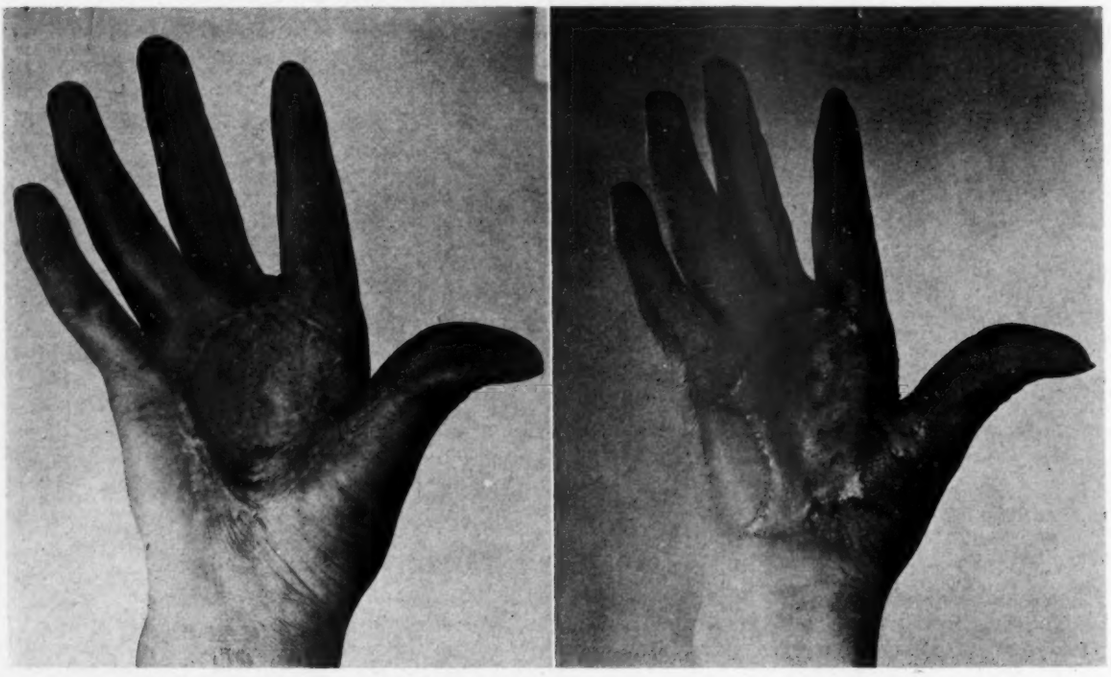
A B

FIG. 2. A, flexion scar contractures at site of suture lines in poorly planned syndactylism operation. B, linear scar replaced by zigzag line following triple Z-plasty of fourth and fifth fingers.



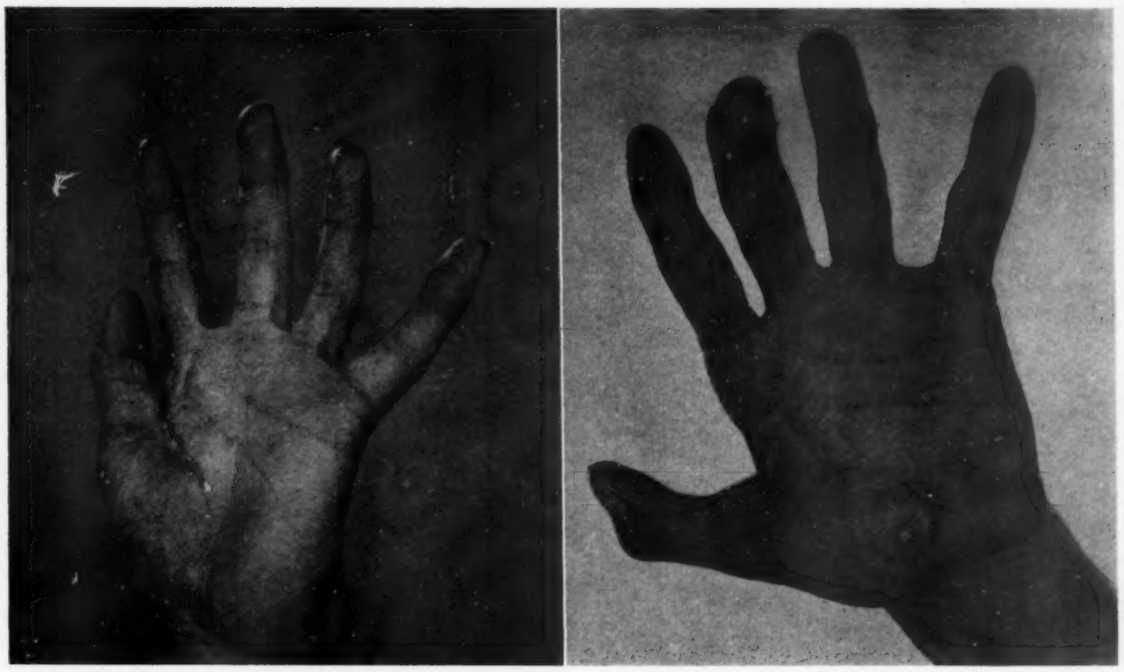
A B

FIG. 3. A, inefficient hand following traumatic loss of fourth and fifth fingers plus complicating severe flexion contracture of mid-finger. B, mid-finger straightened after removal of contracting scar. Resulting defect on finger covered by Z-plasty and that of palm and base of finger by free full-thickness skin graft. (Reproduced through courtesy of U. S. Naval Hospital, Oakland, California.)



A B

FIG. 4. A, inferior result following correction of scar contracture of palm where split skin graft had been utilized. Linear scar along ulnar border adds a further complication. B, replacement of thin graft by free full-thickness skin graft which will give greater elasticity and wear resistant qualities on palm. Also note staggering of edges along graft.



A B

Fig. 5. A, scar contracture of thumb web following trauma. B, after excision and replacement with Wolfe graft.

the length of the hand and fingers. (Fig. 1.) It may be necessary to sacrifice some normal skin along the border in order to create a diamond-shaped defect. The purpose, of course, is to end with a staggered suture line that will not predispose to a potential subsequent postoperative contracture as healing occurs. (Figs. 4A, 4B and 10).

The use of pedicle flaps in the reconstruction of surface defects of the hands is limited to those cases in which it is necessary to replace the subcutaneous fat pad as well. These conditions arise chiefly when after excision of all scar tissue, the underlying tendon, bone or joints may become exposed. Often in cases of this type, future bone, tendon or peripheral nerve surgery may be anticipated. It therefore becomes necessary to cover lesions in this category with a pedicle flap so that such future surgery may be executed without fear of damaging the new skin covering and also that normal tendon and joint function may be expected without adherence to the new covering.

The use of pedicle flaps is more laborious and the covering somewhat bulky by comparison with free grafts. Hence the indications for this covering should be well defined. Whether a direct flap or a tubed pedicle flap is employed is of no difference in the net result. The chief advantage of the direct flap is that its use entails a much more rapid procedure. Against this, the tubed pedicle involves more stages but is a closed wound which eliminates considerable potential contamination during the period of transfer. (Figs. 7A, 7B, 8A, 8B, 9A, 9B, 10A, 10B and 11.)

One final practical point deals with the selection of the donor site from which either a free graft or pedicle flap is taken. Always try to find an area that is free of hair when replacing defects on flexor surfaces. Patients complain endlessly over persistently growing hair in these skin transplants, even to the point wherein they frequently overlook an otherwise excellent functional and cosmetic result. The careful preoperative selection of the site from which the graft is to be taken will readily eliminate this annoying complaint.

SUMMARY

1. All incisions, suture lines and skin graft edges on hand and finger surfaces must be calculated so that they will fall either transversely or obliquely across the longitudinal axis.

2. Free full-thickness skin grafts give the best surface-bearing qualities and maximum degree of elasticity on flexor surfaces. Thick split-thickness grafts provide adequate covering for extensor surface defects and are pre-

FIG. 6. A, healed burn scar contractures on extensor surfaces.

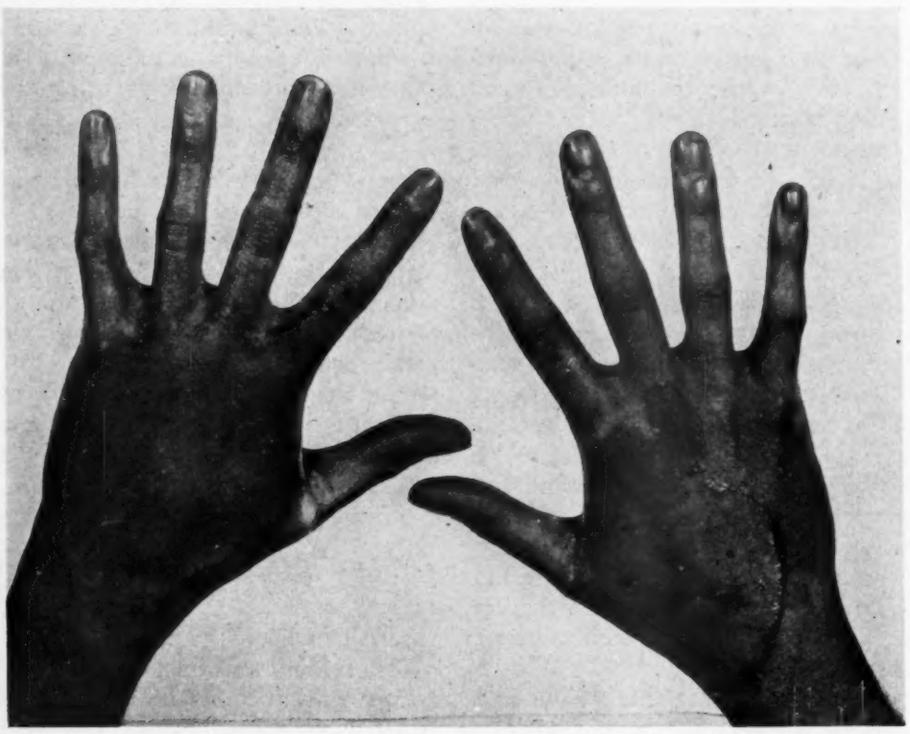
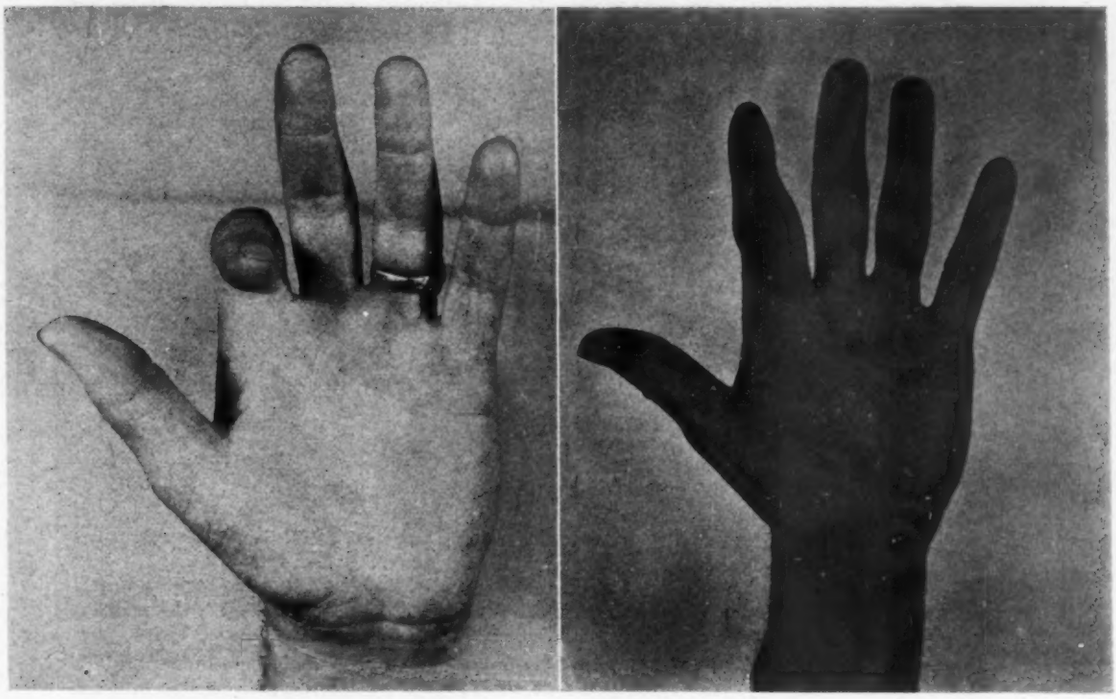
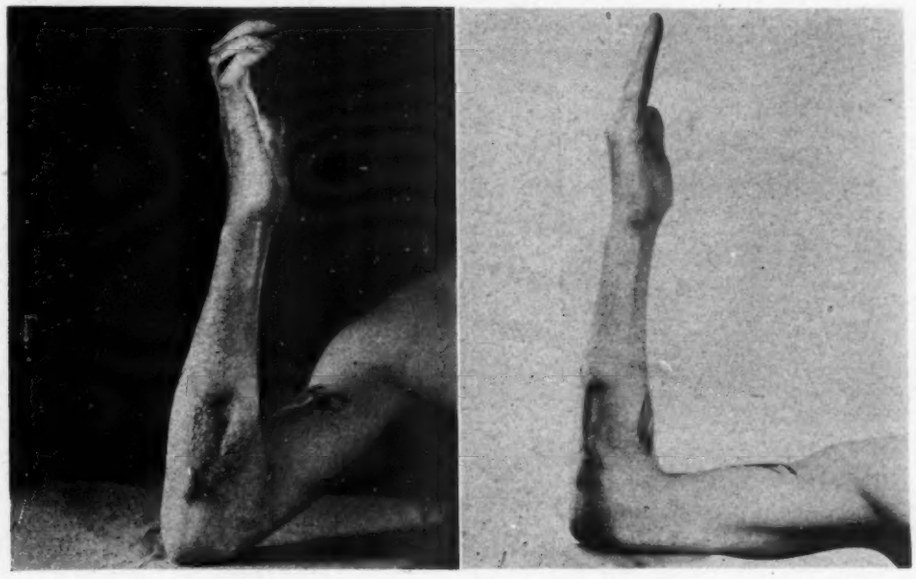


FIG. 6. B, after replacement with thick split-thickness skin grafts. This type of covering gives excellent results on extensor surfaces and its application involves simpler technics.



A B

Fig. 7. A, deep flexion contracture of index finger. Excision of scar left tendons uncovered. B, correction following application of direct flap of skin plus subcutaneous fat. Functional result excellent but flap coverings are always more bulky.



A B

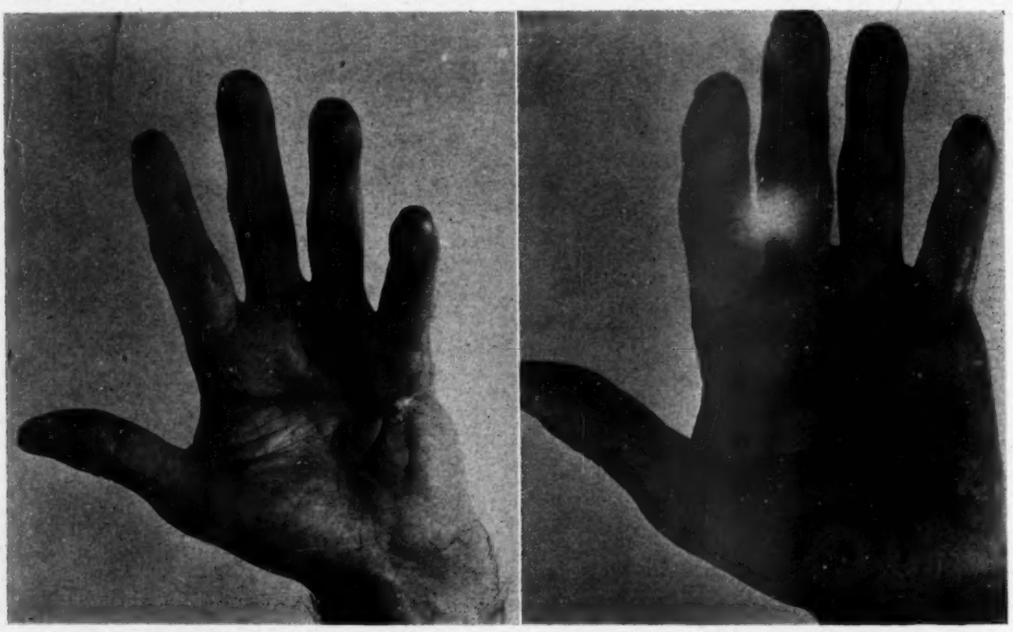
Fig. 8. A, flexion contracture of ring and little finger due to deep scarring of upper arm. Defect had been repaired elsewhere with pinch grafts with no improvement. B, scar excised and underlying muscles freed. Defect covered by adjacent border flap of skin and subcutaneous fat. Donor area from which flap was procured closed with split thickness skin graft.

ferred in this area because of the simpler technic associated with their use.

3. The use of pedicle flaps is reserved for those instances in which it is necessary to carry subcutaneous fat with the skin grafts. This condition arises primarily in covering exposed

A B

FIG. 9. A, healed deep wound with loss of skin and underlying extensor tendons to index, mid and ring fingers. B, after removal of all scar, the defect was covered by a direct flap of skin and subcutaneous fat. When healed and softened, this covering was re-elevated and the underlying tendon surgery completed.



A B

FIG. 10. A, healed deep scar of ulnar border of palm with injury to ulnar nerve and flexor tendons of fourth and fifth fingers. B, replacement by direct flap of skin and subcutaneous fat. Ulnar nerve and tendon surgery completed at a later date.

tendons, bone or joints, or when it is planned to re-elevate the graft at a future date for the purpose of carrying out subsequent tendon, bone or joint surgery.

4. When adequate skin and subcutaneous tissue is found in the border flaps after removal of a contracting scar, the use of the Z-plasty will frequently give rise to the most ideal final result.

Fig. 11. This problem was similar to that of Figure 9A. The defect, however, was covered by a previously tubed pedicle flap. This method is much slower than when direct flaps are used but has the advantage of offering closed surface areas at all points, thus eliminating contamination.

DISCUSSION

Sterling Bunnell (San Francisco, Calif.): It was my good fortune to have seen and admired the work of Dr. Greeley at the Oakland Naval Hospital, and I am in complete agreement with his paper.

In furnishing cover to a hand we must consider: (1) liberation for nutrition, (2) freedom for complete motion and (3) special tactile surface. Skin applied as a mere patch falls far short of this.

A scar binds a hand and pulls from all directions, both surface and deep, spoiling the *nutrition*. Strangled nerves, blood and lymph vessels need liberation. If the cicatrix is in the wrist or forearm, which is the only source of supply to the hand, it pulls to itself from all directions, the effect being a veritable girdle even if the cicatrix covers only one-third of the circumference. To liberate we excise the complete scar, not leaving any cicatricial borders. The edges are then undermined until the skin retracts to its normal tension. At a later operation the deep scar is excised. Then the hand opens up, is liberated and can breathe again and thrive. All of the tissues will improve.

For *freedom of motion* there should be ample skin to cover the hand when in every possible position, and of freedom from any restricting scars. Grafted skin itself, whether by the free or pedicle method, expands enough to cover with normal tension, but it is the borders that contract and inhibit motion. If borders are placed along directions of push and pull, that is, if they cross flexion creases at or near a right angle, they will be subject to the irritation of push and pull and so will contract to a hypertrophic cord limiting motion.

Some examples are as follows. A longitudinal scar along wrist, hand and fingers, whether volar or dorsal, will result in flexion contracture. A longitudinal scar on the back, front or side of the wrist will become a contracting cord as the wrist is a universal joint. A scar across the dorsum of the hand will contract and limit opposition of the thumb. A scar paralleling any web will make a flexion contracture inhibiting spreading of the adjoining digits. In a finger, a scar, if longitudinal, should be in the mid-lateral line. Only this line is free from push and pull. A laterovolar or laterodorsal longitudinal scar will, from motions of the finger, become a contracting scar. Skin grafts across the thumb cleft should be diamond-shaped, reaching from the hinge in front to the hinge in back so as to give free abduction of the thumb. All skin grafts, whether free or pedicle, should have their borders so placed that they are free from push and pull. If they are not, they should be zigzagged or waved. All this is because the hand is a mobile organ.

The hand is a tactile organ. Whenever possible the pulps of the first three digits, the eyes of the hand, should be covered by normal hand skin with its nerve supply to give stereognosis. This is done by transposing good skin in place of grafted skin or by filleting a finger to use its tactile pulp.

Dome-shaped pedicles are grotesque. They do not convey more skin as it is the borders that limit

motion. The surplus fat is parasitic. The pedicle requires two operations to be defatted. A pedicle flap to the hand should be flat relying on the rich circulation between the skin and the fat.

A final point is that hands are prone to stiffen. Any open wound stiffens a hand. Therefore, all pedicle skin flaps to hands should be rendered aseptic by either tubing them or closing them in with skin graft.

Alfred W. Farmer (Toronto, Canada): I wish to express myself as being in complete accord with Dr. Greeley on all that he has stated in his paper, and after hearing the Master, there is not much left for me to say.

There was one point that I thought I should mention, however, and it was related not to a matter of technic and how one does the operation, but whether it should be done at all. In all hand cases, one sits down with the patient beforehand and goes over with him what he is going to do with that hand in the future, if possible. It may be badly injured and he will never return to his previous work at all. He will have to look for a new job, and there is no use doing a lot of unnecessary, high-class technical surgery on a hand that is not going to be any use to him for the job to which he is not going.

The next point that I was going to make has already been made by Dr. Bunnell, that is, direct shifts of pedicles to hands do not have to be left open. As a matter of fact, it is common practice, of course, to close them, either by a partial-thickness skin dressing or tube. By shifting the skin which is based on vessels, one can obtain a long pedicle for a direct shift without any trouble. For instance an abdominal flap of considerable size may be shifted directly if based on the superficial epigastric vessels.

In adduction contractures of the thumb, in my opinion, the most important joint to have free motion, is the carpometacarpal joint. This means that the incision in the web must be deep, very much lower than it is in a normal hand, because there may be some return of contracture. Into the web is placed a free graft or a pedicle graft, usually the latter.

Also, when that is done, it is necessary to free the muscles at their insertions, and it is not necessary in my opinion to reinsert them carefully by any complicated methods. There is enough reattachment with fibrous tissue to give one good power in adduction of the first metacarpal bone.

Attention must be paid in grafting to the webs of the fingers. Very often it is not possible in large grafts of the dorsal surface of the hand to graft so that in one stage the webs are satisfactory. If they are going to be satisfactory extra skin has to be inset, and those lines which are made in the webs must be long. I do not think there is anything at all against putting on the large graft and doing the minor operations with a little extra skin at a later date.

Nothing was said about splinting of the hand, particularly in relation to the grafts on the anterior surface. Following replacement with free grafts on the anterior surface (and particularly in children) prolonged postoperative splinting in a position of extension is a necessity unless one is willing to undertake further operative procedures. When the patient goes home, and for many months after the grafts have been placed on the anterior surface, it is necessary for a child to wear a splint at night and probably for the rest period in the day, to hold the hand in full extension and not in the relaxed position, or shrinking will occur and the patient will have, particularly in the syndactylism cases, a return of contracture. One can accept that as inevitable if one wishes to do plastic operations on them at a later date.

Another point is that very often amputation of a finger or portion of a hand is indicated or dictated due to the economical point of view. To do a complicated series of operations for a contracture in the hope of getting a mobile useful hand or finger is not dictated when the whole situation can be settled by amputating that finger or a section of a hand, using the skin from the amputated finger either as a free graft for other portions of the hand or using it as a pedicle graft on the dorsal surface or on the anterior surface of the hand, as the case may be.

The little finger deserves special consideration in grafting of the dorsal surface of the hand in that the fifth metacarpal is so mobile and there is a tendency not to place the lateral scar far enough around on the side of the hand.

I think those are the main points I had in mind in discussing Dr. Greeley's presentation.

Paul W. Greeley (closing): I am sure that we all agree with both Dr. Bunnell and Dr. Farmer in everything that they had to contribute to the initial points that I brought forth.

I would like to re-emphasize the point that Dr. Bunnell made, that is, in removing the contracting scar, it all has to be removed, not just part of it but all of it. It has to be removed widely. I think many times an individual who is not too familiar with this type of surgery is apt to be a little bit timid and will remove only what he thinks is necessary to straighten out the fingers at that particular moment. However, if some scar has been left, it may cause the contracture to recur.

Even though one has to put on large grafts, it is of minor consequence. Large grafts have to be put on if the defect is large. In other words, always make certain that all of the scar is removed so that there will be no possible tendency toward contracture, irrespective of the amount of surface covering which you have to apply.

OBSERVATIONS ON THE MANAGEMENT OF SUPPURATIVE ARTHRITIS OF THE KNEE JOINT*

OSCAR P. HAMPTON, JR., M.D.
St. Louis, Missouri

THE purpose of this paper is to outline significant changes in the management of suppurative arthritis of the knee joint developing and based upon experiences during World War II in the Mediterranean Theater of Operations. Suppurative arthritis in this experience was superimposed on wounds and, therefore, the more comparable infections in the knee joint in civilian surgery are those following penetrating, lacerated and operative wounds. It appears, however, that the same principles are applicable to blood-borne suppurative arthritis.

Wounds involving the knee joint are serious wounds[14] not only because the damage at wounding is immediately prejudicial to subsequent function, but of greater importance because each is potentially a suppurative arthritis endangering life and limb. The reported results with suppurative arthritis of the knee joint during World War I and the early part of World War II revealed that the ravages of sepsis had often lead to death or amputation. Even if these had been avoided, many joints became totally destroyed resulting in fusion.

Frankau[9] records that in the British Army in the early stages of World War I, principally because of sepsis, the death rate from wounds of the knee joint was high and that 80 per cent of those complicated by fracture resulted in amputation. Later in that experience, the amputation rate fell to 25 per cent in 1916 and to only 7 per cent in 1917, while the death rate declined to 8 per cent. Buxton reporting 273 wounds of the knee joint treated in a base hospital during two Libyan campaigns in World War II cites incidences of 34.8 per cent suppurative arthritis, 4.4 per cent amputation and 1.8 per cent mortality. Ogilvie,[20] also of the British Army, while recommending free drainage for suppurative arthritis, based upon experiences in World War II, stated that the battle against sepsis was usually decided in four days and that, if in that time the septic process was not controlled, amputation was necessary to save life.

The French in the last and this war accepted that once a suppurative arthritis was established, the joint was doomed and that life and limb were endangered. Fear of these dire consequences and a desire to provide adequate drainage had lead them to employ primary resection as a prophylactic measure in the severely damaged joint, recognized as especially vulnerable to sepsis, and secondary resection as a therapeutic measure for acute or chronic suppurative arthritis if the infection failed to respond quickly to long anterolateral incisions and thorough immobilization. Throughout World War II, French, Russian[15] and German[25] surgeons practiced resection extensively rather than risk the hazards of knee joint suppuration.

In American and English experience during and following World War I and the early part of World War II, the loss of life or limb had not been sufficiently frequent to warrant this radical almost prophylactic operative procedure. Wide incision, drainage and immobilization, and in World War II, the use of chemo therapy, had usually controlled the infectious process without death or amputation although residual function was often nil or greatly impaired. Pool,[24] in the Surgeon General's history of World War I, however, recommended resection for suppurative arthritis superimposed on a severely damaged joint.

Suppurative arthritis complicating wounds of the knee joint may be classified as potential and established. With every penetrating wound, the joint is contaminated and a potentially suppurative arthritis exists. Sepsis is not established, however, until there is septic decomposition of tissues destroyed by the agents of wounding or by the action of the infecting organisms with the formation of pus. Usually, several days and not merely a few hours are required for suppurative arthritis to become fully established, and then there is continuing destruction of articular cartilage and other

* From the Department of Surgery, Washington University, St. Louis, Mo.

intra-articular fibrocartilagenous structures by the proteolytic enzymes in the pus.

As was learned in World War I and relearned in World War II, the indicated management of potential or impending suppurative arthritis following wounds of the knee joint includes wide arthrotomy in the location which provides the maximum of intra-articular exposure, thorough excision of all devitalized articular cartilage and small fragments of bone, removal of foreign bodies and old blood clot, thorough irrigation of the joint cavity and closure of the joint space by suture of the synovia. Local and systemic penicillin therapy and thorough immobilization by a single hip spica or Tobruk splint were highly important adjuvants in avoiding established sepsis during World War II. This regimen held the incidence of established suppurative arthritis to a minimum, and it appears reasonable to state that this complication developed only when foreign material and intra-articular devitalized tissue were not or could not be thoroughly excised or when soft tissue loss was so great that the joint necessarily was left wide open.

In the early phases of this experience, not infrequently an infectious process was prevented by thorough intra-articular surgery; but because the time lag from wounding to surgery had exceeded eight hours, fear of enclosing a suppurative process led to the omission of synovial suture in order to provide continuous drainage. This was done despite the advice of Pool,[29] following World War I, who had stated that after the joint cavity had been thoroughly cleaned, closure of the synovial membrane was permissible and indicated for as long as twenty-four hours after injury. He attributed the poor results in wounds of the knee joint in the early part of World War I, in part, to "an undervaluation on the part of surgeons, of the resistance to infection which the synovial membrane of the joint offers." Others [5,6,8,16] also have emphasized apparent antibacterial properties of the synovial fluid.

When closure was omitted following adequate intra-articular surgery, a suppurative arthritis with continuing destruction of articular cartilage was usually avoided, but wound healing was slow and scar tissue formation about the suprapatellar pouch was excessive. The resulting limitation of motion appeared to exceed that which the severity of the wound seemed to warrant. With increasing experience, closure of the synovia was employed in wounds of twenty-four or more hours' duration. Without doubt, the desire to close the joint, stimulated the surgeon to more thorough excisional surgery in the joint.

Other early observations indicated that, if gross dirt and foreign bodies were removed, the incidence of established suppurative arthritis varied with the extent of damage to the joint and the adequacy of the excisional surgery.[11] This complication seldom, if ever, was observed when the intra-articular bone and cartilage damage was minimal or absent and it was, indeed, rare, when the damage was moderate if surgery was adequate. With only moderate damage and inadequate intra-articular surgery, however, sepsis with destruction of the joint often followed. Compound comminuted fractures of the patella or condylar fractures of the femur or tibia were a likely source of such a septic process. With severe intra-articular damage, septic arthritis was the rule. In each, the joint had been destroyed at wounding and an ankylosed knee in the functional position was the best that could be expected. Even though the joint was destroyed and prolonged suppuration with toxemia was likely, resection of the joint was not considered.

During the phase of these observations, the therapy of suppurative arthritis was based upon wide parapatellar incisions for continuous drainage, immobilization and antibiotics as had been recommended by practically every authority,[1,3,10,13,18,19,20,21,26] reporting on this subject, prior to and during the early phases of World War II. Fortunately, the regimen was usually successful in preventing loss of limb or life. In some, the infectious process subsided without further septic destruction of the articular surfaces of the femur and tibia but scar formation about the incisions appeared to limit excessively the subsequent function. In many others, however, there was lingering sepsis, slow destruction of the joint[23] and low grade toxemia. In the severely damaged joints with suppurative arthritis, drainage was always prolonged and there was usually evidence of chronic sepsis. More favorable results appeared possible.

Subsequently, the therapy of suppurative arthritis was revamped upon the basis that, with foreign bodies and material removed, suppuration within the knee joint developed and persisted only when there was retained de-

vitalized articular cartilage, a structure of recognized avascularity and low resistance to infection, and that adequate and complete drainage of fluid from the knee joint was not surgically feasible, drainage incisions serving only as safety valves to prevent the accumulation under pressure of fluid within the joint. Since drainage was often ineffective, it did not prevent the continuing destruction of articular cartilage and the menisci and, in addition, continuous drainage impaired any antibacterial action of the synovial fluid. Moreover, drainage openings left the joint open to secondary invaders and jeopardized the nutrition of the articular cartilage. Finally, the subsequent range of knee joint motion was excessively impaired even if sepsis was controlled.

It was, therefore, concluded that continuous drainage of the knee joint cavity was not only ineffective but was contraindicated and that the therapy of established suppurative arthritis should be based upon the same principles which had been successfully employed in the management of potential or impending infection. To that end, the following regimen was applied in the presence of impending or established suppurative arthritis regardless of the time lag since wounding or the duration of the sepsis.

The joint cavity was exposed by adequate medial and/or lateral parapatellar incisions. Any retained foreign bodies were removed, of course, and all devitalized articular cartilage destroyed at wounding or by sepsis was excised. In sepsis of several days' duration, the menisci were often soft and friable and, if so, these too were excised. Old blood clot and exudate were cleaned from the joint cavity. Only healthy living tissue remained. Thereafter, the joint synovia was closed. In the presence of soft tissue loss, rotation of a flap of skin or a fascial graft was employed to achieve a closed joint. Only when hope of future function of the joint was abandoned was it left open. Penicillin solution was instilled into the joint cavity, and, obviously, the closed joint aided in the retention of this antibacterial agent. The extremity was then well immobilized in a single hip spica or, on occasion, a Tobruk splint. Penicillin therapy systematically was initiated.

Thereafter, any reaccumulation of fluid in the joint was aspirated through a window in the cast at intervals of twenty-four to forty-eight hours with the reinstillation of penicillin. As a rule, however, little fluid reaccumulated. When danger of continuing sepsis (which would have resulted only from incomplete intra-articular surgery) was past, usually five to seven days later, the remaining soft part wound was sutured. When the wound was healed sufficiently, usually about twelve to fourteen days after the arthrotomy, immobilization was discontinued in favor of mobilization in balanced suspension using a Thomas splint with Pierson attachment. Active and passive movement of the knee joint was gradually increased.

This regimen, when the intra-articular damage did not preclude its application, was highly successful in reducing morbidity and predisposed to the maximum return of function of the extremity. In those joints so severely damaged at wounding or by the septic process that complete excision of all devitalized tissue precluded subsequent function of the joint, the sepsis was eliminated and what is believed to be the optimal result was achieved by resection of the joint. These resections were, in effect, only thorough excision of dead and devitalized bone and cartilage which had been destroyed by the missile of wounding or by the infectious process. The amount of dead tissue predetermined the extent of excision and, therefore, the resulting shortening of the extremity. The lower end of the femur and the upper end of the tibia were carefully held in approximation thereby eliminating the dead space and predisposing to rapid union and wound healing.

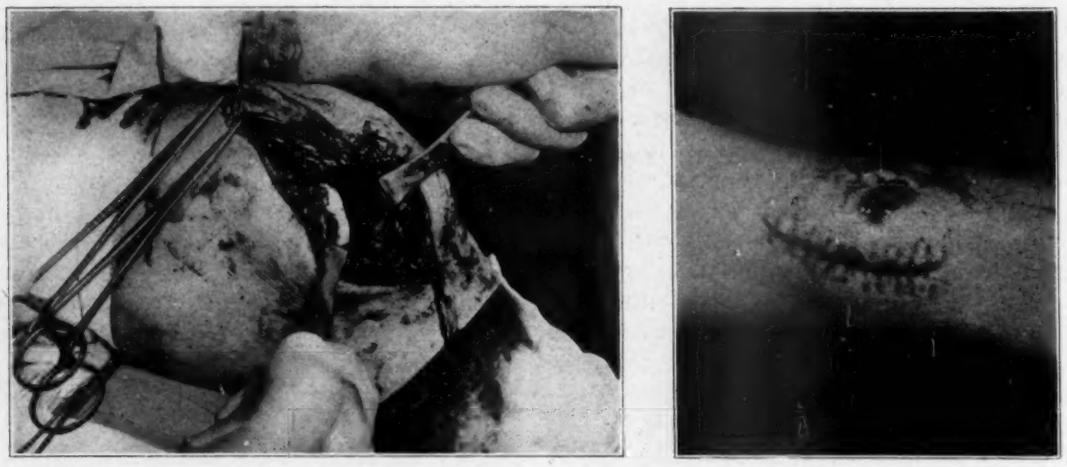
Several illustrated cases are herewith reported as typical of this experience:

CASE REPORTS

Case 1. This patient received a penetrating wound of the left knee on medial side on July 1, 1944. Several hours after injury, the knee joint was opened through a medial parapatellar incision and the foreign body embedded in the medial femoral condyle was removed. The joint capsule was sutured. Penicillin was instilled in the joint, systemic penicillin therapy was initiated, and a toe-to-groin plaster cast was applied.

When observed several days later in a base hospital, the knee was painful and swollen and pus was oozing from the incision. Through a large needle, an effort was made to irrigate the joint and penicillin was instilled. The patient was running a low grade septic course, with temperature ranging from 98° to 101.4°F.

Thirteen days after injury, the temperature was 101°F., the knee was swollen, boggy and tender, a



A B

FIG. 1. A, Case 1. photograph of the interior of the knee at the time of the second arthrotomy. The edge of the damage to the articular cartilage is visible. Note the intense hyperemia. B, in three weeks the operative wound is healed and the joint is normal in size.

C D

FIG. 1. C, Case 1. reproduction of anteroposterior roentgenogram taken nine months later. The extent of condylar damage is demonstrated. D, the range of knee motion nine months later. Complete extension was possible but is not shown here.

seropurulent discharge leaked from the joint and maggots crawled from the wound.

The joint was reopened and the old wound was extended. Maggots again were present. A piece of woolen cloth and from beneath it a devitalized area of articular cartilage about 1 inch in diameter depressed into a defect in the medial femoral condyle were removed. The defect was trimmed evenly and the joint was thoroughly inspected for further damage but none was found. The medial meniscus was dull in appearance but was not friable, so it was not removed. After thorough irrigation, the synovial membrane of the capsule was closed and the joint was filled with penicillin. Immobilization was achieved by means of a Tobruk splint.

On the second and third days after operation, a small amount of synovial fluid was aspirated and the joint was irrigated and filled with penicillin through a large needle. On July 19, six days after the surgery, the soft part wound was sutured. Quadriceps exercises were instituted.

On August 7 the wounds were healed and movement of knee joint was started. All joint reaction subsided and, five weeks after surgery for the suppurative arthritis, the active range of motion was about 15 degrees. The patient was then evacuated to the Zone of the Interior with removable splinting for use at night as a precaution against flexion contracture.

At a check-up examination made on April 5, 1945, nine months later, the patient was observed with all wounds healed and an active range of knee

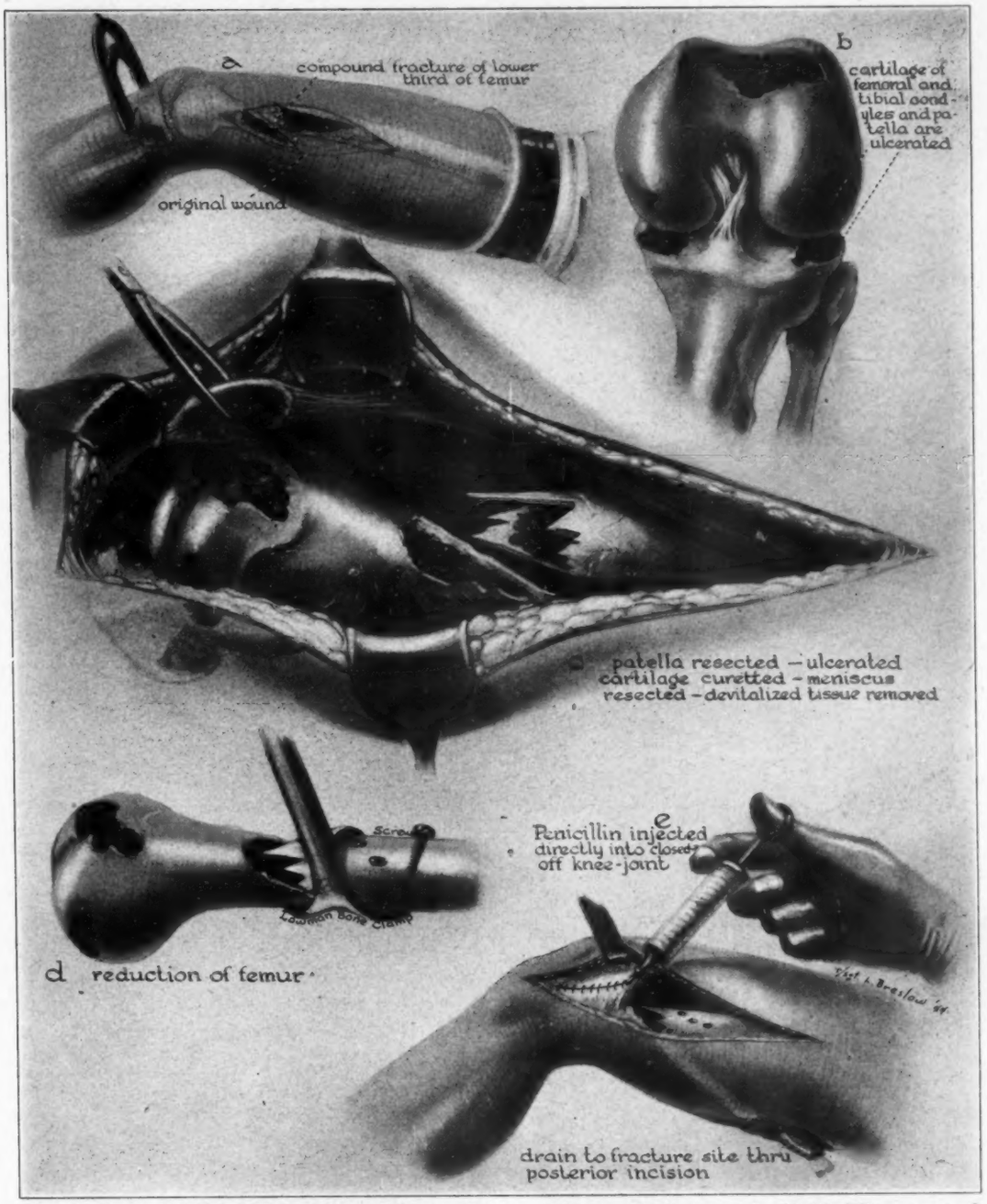

a
compound fracture of lower third of femur
original wound
b
cartilage of femoral and tibial condyles and patella are ulcerated
c patella resected – ulcerated cartilage curetted – meniscus resected – devitalized tissue removed
Lowman bone clamp
d reduction of femur
e
Penicillin injected directly into closed off knee-joint
drain to fracture site thru posterior incision

Fig. 2. Case II. Artists's conception of the surgical procedure carried out on April 6th. The extent of bone loss is not shown. (From *Ann. Surg.*, 123: 249, 1946.)

motion from full extension to 100 degrees. The knee was reasonably stable and the patient had no complaint other than his restricted motion.

Comment. This case illustrates the necessity for and the effectiveness of an aggressive surgical program in early knee joint sepsis. Obviously, drainage alone would not have controlled the sepsis or have prevented complete destruction of the joint. The excisional surgery was the most important factor in the achievement of excellent result. It may be noted that, in the presence of inadequate initial surgery and with devitalized tissue retained, penicillin therapy *did not prevent sepsis.*

Case II. A soldier received a high explosive shell fragment wound on February 20, 1944, with a compound comminuted fracture of the left femur in the distal third. After transfer to a base hospital

A

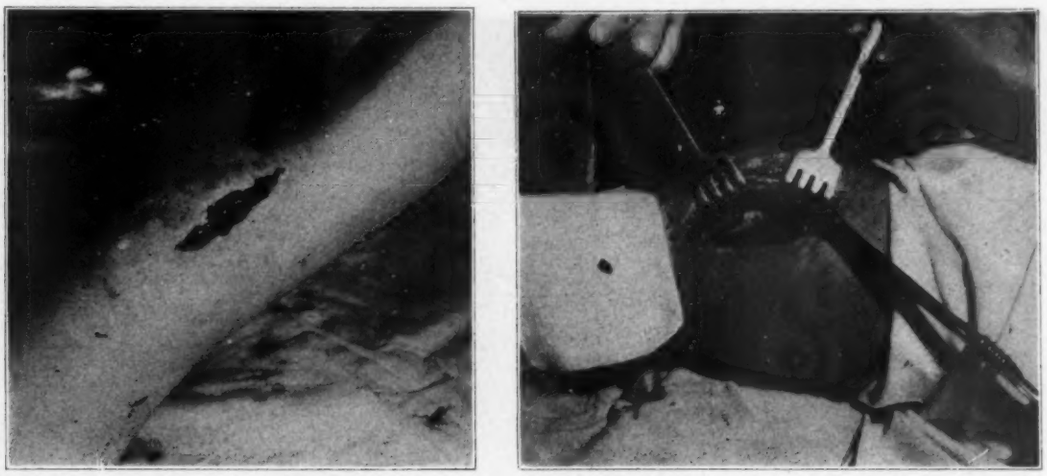
FIG. 3. A, Case III. anteroposterior and lateral roentgenograms show the multiple foreign bodies in the joint.

B

C

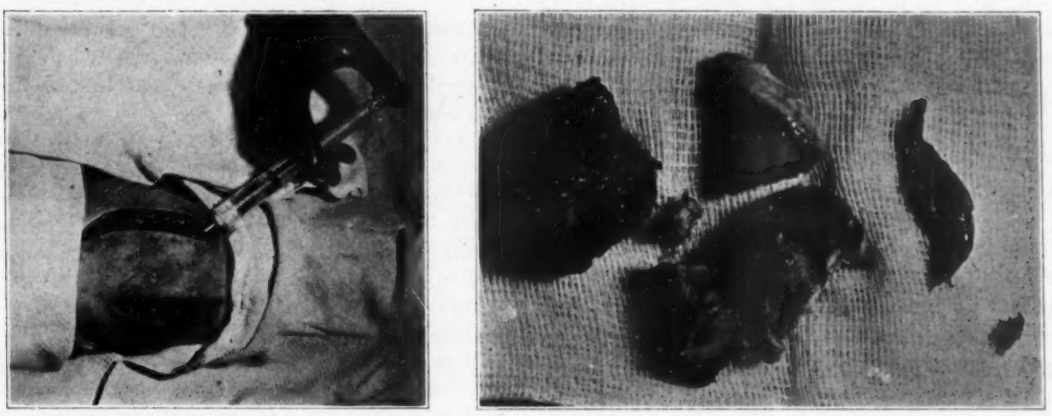
FIG. 3. B, Case III. photograph of the bulging knee, before surgery, on the fourteenth day after injury. C, several areas of damage to the articular cartilage are revealed by the medial arthrotomy incision.

and the institution of skeletal traction, the wound became grossly septic and it was obvious that the left knee joint was swollen. Following the aspiration of purulent material, the joint was drained by bilateral parapatellar incisions and the fracture site was drained by extending proximally the compounding wound over the lateral surface. Thereafter, the patient ran a low grade septic course. Purulent drainage from the fracture site and incisions of the knee continued.



A B

Fig. 4. A, Case IV. shows the swollen joint and the granulating wound, with pus draining from the opening in the center, as they appeared in the operating room on October 21, 1944, fifteen days after the wound had been received. B, photograph of the medial arthrotomy iucision. Inflamed synovial membrane and the partially necrotic cartilage of the comminuted patella are poorly visualized. The small piece of woolen cloth is shown on the gauze at the left of the incision. The quadriceps pouch was filled with a coagulated fibrinous exudate.



C D

Fig. 4. C, Case IV. following removal of the patella and cleansing of the joint, the synovial membrane of the arthrotomy incision and the defect in the old wound were sutured (plus a few sutures in the tendon). The joint was filled with penicillin. D, the fragments of patella, some of the fibrinous exudate and the bit of cloth removed from the joint are shown.

Six weeks later, after penicillin therapy was instituted and 1,500 cc., of blood were given, abscesses in the proximal thigh were drained by liberal incisions and posterior drainage of the fracture site was established.

Five days later, through the compounding wound, the comminuted fracture was stabilized in reduction by four screws and the knee was opened by extending the incision distally. The articular cartilage of the patella was soft, eroded and detached. There was spot erosion of the articular cartilage of the femur and tibia at the points of contact and where the patella had rested upon the femur. The patella was removed, the edges of eroded cartilage were trimmed and the bases were curetted. The joint was thoroughly irrigated, closed and filled with penicillin.

All reaction about the knee subsided and the wounds of the thigh healed slowly. Two weeks after surgery on the knee joint, passive motion through a 10 degree arch was carried out daily until the patient was evacuated to the Zone of the Interior in a hip spica in May.

The fracture of the femur united but it was necessary to remove two small sequestra and the screws before wound healing was achieved. Knee motion was limited to about 15 degrees. Unfortunately, in late December, of 1944, he suffered a refracture of his femur at the site of bone loss. Thereafter, immobilization was quite prolonged.

E F

FIG. 4. E, Case IV. the skin has been sutured and the joint resplinted (October 26th). F, demonstrates the range of active painless motion of the knee on November 17th. Quadriceps power was sufficient to extend the knee but a hand held the foot for the photograph.

Comment. The excisional surgery within the knee joint followed by closure and adequate penicillin therapy prevented the continuing destruction of the articular cartilage of the joint. Ten to 15 degrees of motion was preserved. This appears preferable to the fusion which probably would have occurred with only drainage of the joint. It appears reasonable to state that if the low grade suppurative arthritis had been his only problem, a greater range of motion in the knee would have been obtained. The range of knee motion following compound comminuted fractures of the lower end of the femur is always markedly restricted particularly when prolonged immobilization is necessary.

CASE III. This patient was wounded at Anzio on March 29, 1944, by multiple small high explosive shell fragments. It was the judgment of the surgeon in the forward hospital that arthrotomy would not be effective and so the wounds were not débrided.

He was received in the base nine days later with a temperature ranging from 101° to 102°F. The knee joint was painful, hot and swollen, and pus oozed from the multiple wounds. Penicillin therapy was initiated.

The knee joint was opened through a medial parapatellar incision and the bloody, pus-filled joint was thoroughly irrigated. Several embedded metallic foreign bodies were removed from the articular cartilage of the femur. The medial meniscus was friable and partially devitalized so it was excised. Through a lateral parapatellar incision, areas of devitalized articular cartilage and a friable lateral meniscus were removed. After thorough irrigation, the synovial membrane of each incision was sutured, the joint was filled with penicillin and the extremity was immobilized by hip spica.

On each of the next four days, through a window in the cast, the synovial fluid was aspirated and the joint was irrigated and filled with penicillin daily.

All joint reaction subsided and nine days after the surgery for suppurative arthritis, the skin was sutured. The wounds healed and active knee motion was instituted. On May 8th, a little over five weeks after the wounds were received and four weeks after the surgery for the suppurative arthritis, the range of active knee motion was 30 degrees. A later report following his evacuation to the Zone of the Interior was not received but it is believed that he obtained a range of motion adequate for ordinary function.

Comment. The sepsis following lack of initial surgery was controlled by excision of the intra-articular foci *before* the undamaged articular cartilage was digested and destroyed. Drainage incisions probably would have been ineffective. The program for suppurative arthritis was effective in salvaging the joint.

CASE IV. This soldier received a penetrating wound of the right knee anteriorly with a compound comminuted fracture of the right patella. Ten hours after injury the joint was opened by enlarging the compounding wound and the foreign body was removed, the joint irrigated and the capsule closed. The comminuted patella was not

removed and the intra-articular structures were not thoroughly inspected. Penicillin was instilled into the joint and systemic penicillin therapy was initiated. A long leg cast was applied.

He was received in the base hospital five days later where penicillin therapy was continued. The patient ran a low grade septic course with temperature ranging from 99° to 101°F. The knee was painful, swollen, boggy and tender.

Fourteen days after injury, the joint was opened through a medial parapatellar incision. A small piece of woolen cloth was removed from the joint. The severely comminuted patella was excised. The cartilage of the patella was greyish yellow in color and one fragment appeared necrotic. Gelatinous, fibrinous exudate was cleaned from the joint and the suprapatellar pouch.

After thorough irrigation, the synovial membrane was closed and a few sutures were placed at the quadriceps tendon. The old wound was excised to the depth of the fascia and an opening into the joint was closed by suture. The joint was filled with penicillin and a Tobruk splint provided immobilization. On each of the next four days, the joint was irrigated through a large needle and filled with penicillin.

Five days after surgery for suppurative arthritis, the skin of each wound was sutured. Immobilization was continued until eighteen days after surgery. Then active knee motion was begun and only night splinting was used. Five and one-half weeks after surgery, there was no reaction about the joint, quadriceps power was fair and there was 45 degrees of active knee motion.

Comment. A compound comminuted patella was frequently the nidus of knee joint sepsis. The traumatized cartilage remains and obviously the joint remains open. The ineffectiveness of penicillin therapy when excisional surgery is inadequate may be noted. In this case, removal of the comminuted patella and thorough cleansing of the joint of all foreign material, blood clot and pus *before* proteolytic digestion of the articular cartilage began followed by adequate immobilization and penicillin therapy led to a functioning joint. It is believed that a much less desirable result would have been obtained by mere drainage incisions.

Case v. This soldier was wounded on January 8, 1944, by high explosive shell fragments. He received a traumatic amputation in the upper third of the left thigh and a compound comminuted fracture of the medial condyle of the right tibia which extended into the knee joint. Forty hours after injury, the traumatic amputation was completed by the guillotine method and minimal débridement of the penetrating wound of the right tibia was performed.

He was received in the base hospital on January 21st, eleven days after his injury. The amputation stump was clean but there was profuse drainage from the upper tibia. Thereafter, signs of a suppurative arthritis of the knee developed and bilateral parapatellar drainage incisions were made. Despite penicillin therapy and repeated blood transfusions, sepsis continued with the temperature ranging up to 102°F. Abscesses developed in the proximal and mid-thigh and these were drained. Later roentgenograms revealed septic destruction of the articular surfaces of the femur and tibia.

He was seen in consultation on March 23rd, over two months after his injury. He appeared quite ill and amputation was considered as a lifesaving measure. He had been kept alive with a total of 4,500 cc. of blood.

During the next two days, an additional 1,500 cc. of blood was given and on March 26th, surgery for this extensive suppurative arthritis was performed. The old incisions were extended proximally in order to drain abscesses of the thigh and another abscess in the calf was incised. A long medial parapatellar incision and reflexion of the patella disclosed that the joint cartilage, including that of the patella, had been totally destroyed by the septic process. The old articular surfaces and the eroded underlying bone was excised and the patella was removed. The wounds were thoroughly irrigated. The bones were held in approximation by a wire loop passing through the anterior portions of the femur and tibia. The old wound edges were excised but none were sutured. A hip spica provided immobilization.

During the next two days 1,500 cc. of blood were given and penicillin therapy was continued. The only temperature rise above 100°F. during the first five days after operation occurred following a mild transfusion reaction.

On April 1st, six days after the resection of the joint, the hip spica was removed in the operating room and an old blood clot was irrigated away. The wounds were partially sutured with drains to the back of the old joint space and to the calf abscess. On this day, 1,500 cc. of blood was given. On April 7th, six days later, an additional incision in the calf for drainage of this abscess was necessary and on that day, 500 cc. of blood was given. Thereafter, all wounds granulated to almost complete healing and the knee fused to stability. In late April, he was transferred to a Canadian hospital and since then follow-up information has not been available. At that time there were no sinuses to the bone and the wounds were healing. It may be of interest that he received a total of 12,500 cc. of blood over a three months' period.

A

FIG. 5. A, Case V. anteroposterior and lateral views taken on March 22nd show the erosion of the medial tibial condyle and the destruction of the entire joint.

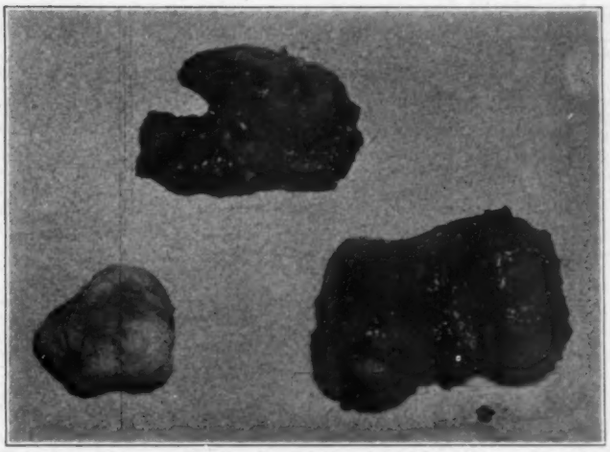
B C

FIG. 5. B, Case V. photograph of the joint exposed at operation on March 26th. The patella has been removed. For photographic demonstration the patella is held beside the destroyed femoral condyles. C, photograph of the resected joint. Shortening in this case was of no consequence because of amputation of the opposite leg.

Comment. The ravages and potential dire consequences of knee joint sepsis, the ineffectiveness of drainage incisions, particularly after septic destruction of articular cartilage, the salvage of a limb and possibly of a life by resection of the knee joint are here illustrated.

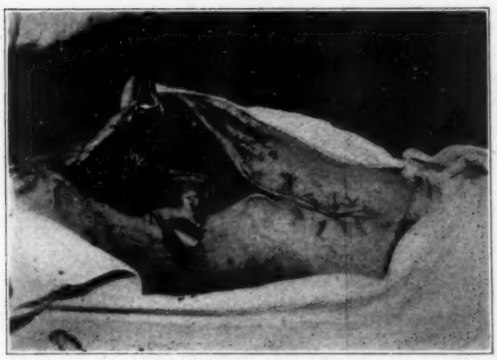
CASE VI. This soldier received a penetrating wound of the left knee on October 18, 1944. A few hours later in a forward hospital, foreign bodies were removed through a small incision. The synovia was closed, penicillin was instilled and a hip spica was applied. Systemic penicillin therapy was instituted.

In the base hospital where he was received a few days later, it was assumed that because the foreign bodies had been removed, intra-articular surgery had been thoroughly performed. Signs of a suppurative arthritis developed and drainage through the wound began. The recommended therapy of re-arthrotomy and thorough intra-articular surgery was not carried out. There was continuing destruc-



D

FIG. 5. D, Case V. the dead, infected tissue has been excised.



E

F

FIG. 5. E, Case V. the medial wound has been partially closed with drainage (April 1st). F, shows closure of the lateral wound and drainage of the calf abscess (April 1st).

G

H

FIG. 5. G, Case V. the medial and lateral wounds have almost healed (no sinuses) on May 23rd. H, the medial and lateral wounds have almost healed (no sinuses) on May 23rd.

tion of the joint surfaces and the patient became quite ill.

He was seen in consultation in December, two months after his injury, and resection of the joint was advised as a means of overcoming continuing sepsis and reducing morbidity.

On January 6, 1945, three months after wounding, the joint was resected and the fragment ends were stabilized in approximation by use of the external skeletal fixation apparatus over which a hip spica was applied. All wound edges were excised but they were not sutured until a delayed surgical procedure three weeks later. The wounds healed and he was evacuated to the Zone of the Interior in a hip spica.

He was observed on March 28, 1945, in a named general hospital in the United States. All wounds had been soundly healed on admission. It appeared that the femur and tibia were uniting by bone in the optimum position. There was shortening of

A

FIG. 6. A, Case VI. roentgenograms made soon after injury revealing moderate intra-articular damage.

B

FIG. 6. B, Case VI. the septic destruction of the joint two months later.

about 3 inches, resulting not from the resection but from bone destruction by the septic process. Resection was an alternative to amputation.

CONCLUSIONS

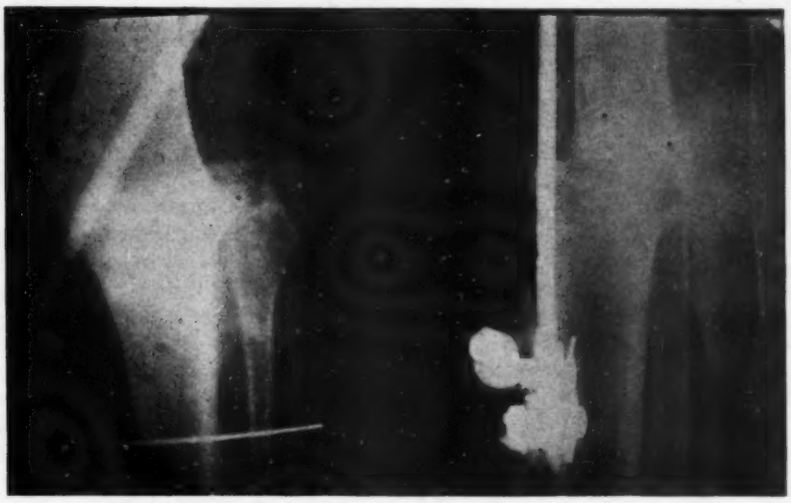
1. The nidus of continuing sepsis following wounds of the knee joint is usually traumatized, devitalized, articular cartilage. Blood clot, coagulated exudate or devitalized menisci provide further pabulum for sepsis.

2. The keystone of the elimination of the septic process is the complete surgical excision of tissue destroyed at wounding or by the septic process.

3. Thorough continuous drainage of the knee joint is not surgically feasible or effective. Drainage incisions serve only as safety valves. Despite them, intra-articular suppuration can persist with continuing proteolytic digestion of articular cartilage.

4. Moreover, continuous drainage of fluid from the joint is contraindicated because any antibacterial action of the synovial fluid is handicapped, the joint cavity is open to secondary invaders, nourishment of articular cartilage may be reduced and excessive scar formation may be anticipated.

5. Therefore, following adequate cleansing of the joint of all potentially septic material,



C

Fig. 6. C, Case VI. the resected joint several days after operation.

D

Fig. 6. D, Case VI. the healed wounds and stable knee a few months later.

the cavity is closed, usually by suture of the synovia, if future motion is anticipated.

6. When the damage at wounding or by sepsis precludes subsequent function, the morbidity can be reduced and the best obtainable functional result may be secured by resection of the joint.

7. This regimen is made possible without fear of grave complications by the availability of effective antibacterial agents, such as penicillin, to protect living tissue from invasive infection.

8. In those instances in which suppurative arthritis responds to open drainage, the open drainage was not necessary and the recommended regimen would have reduced morbidity and lead to a better result in less time.

9. It appears reasonable that, in blood-borne suppurative arthritis not responding to repeated aspiration, immobilization and antibiotics, a regimen of therapy including intra-articular débridement of tissue destroyed by sepsis, removal of coagulated exudate and hematoma, closure of the joint, immobilization

and local and systemic penicillin therapy may be the means of eliminating the septic process.

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DISCUSSION

Harry B. Macey (Temple, Tex.): I think this is quite a timely presentation and I know of no one better equipped to present this subject than Dr. Hampton, who had an extensive experience in the Mediterranean Theater. I am heartily in accord with everything that he has said and I merely want to re-emphasize some of the points that time prevented him from stressing.

Most of the things I will say are commendation of the paper. The problem of treating suppurative arthritis of the knee joint, as he pointed out, is really two-fold: one is the adequate surgical care of the wound; second, the use of antibiotics, chemotherapy and penicillin. They must complement each other. The surgery must be adequate, but, as mentioned by Dr. Hampton, not stressed; the joints should be widely opened and a thorough débridement done for the joint to be in a receptive mood for the chemotherapy and the penicillin which is instituted later. It is impossible to expect a drug such as penicillin, or a sulfonamide, transported in the blood stream to get into devitalized tissue. Therefore, all devitalized tissue should be thoroughly excised.

Secondly, by closing the capsule the traumatized area is going to be bathed by a fluid with a high concentration of penicillin and sulfa.

I think we see this borne out in the blood-borne suppurative arthritis. I have seen very few, but they were treated very satisfactorily with repeated aspiration, injection of penicillin into the knee joint and giving penicillin and sulfa drugs systemically.

I had the experience of treating one patient with a double infection, both staphylococcus and streptococcus. Response was not satisfactory with penicillin alone; however, with the addition of sulfadiazine on about the fourth day improvement was noted. He made a complete recovery and had a normal joint, that is, from early observation.

Clinically, there were no x-ray changes and no symptoms. Therefore, I would be inclined to delay surgery in the suppurative arthritis from blood-borne disease for many days, in the hope that surgery may be entirely avoided.

Again, I want to say that I appreciated hearing this excellent paper and enjoyed discussing it.

Oscar P. Hampton, Jr.: Time did not permit me to emphasize the place of resection of knee joints destroyed by sepsis as I desired. There definitely appears to be a place for this procedure in the management of long standing suppurative arthritis whether it develops following a missile wound or otherwise. For years, continental surgeons have utilized this procedure extensively even before a joint had been totally destroyed by the septic process. During the recent war, we observed that the French and German surgeons performed many resections of the knee joint following missile wounds, many prophylactically before the development of established sepsis. This procedure has rarely been performed in American and English surgery in the interim between the wars and seldom was it chosen during World War II. A fear of opening up normal bone to infection was one factor mitigating against resection.

I would like to point out again that in Case V, bilateral parapatellar incisions for drainage of the suppurative arthritis were of no avail and the continuing septic process completely destroyed the joint. There was further extension up the thigh. Had he not previously had an amputation of the other thigh, it seems certain that amputation would have been selected as the means of eradicating this severe septic process as this patient was indeed severely ill. Following resection of the joint which removed the dead infected material and permitted the approximation of healthy bone, the septic process was controlled, the wound healed and an exceedingly favorable result under the circumstances was achieved.

Case VI, while not as dramatic, illustrates the eradication of severe sepsis by resection of a knee joint. It should be pointed out that resection is reserved for those joints which are so destroyed by the septic process or by trauma that future function is hopeless. The degree of shortening which results is determined by the extent of destruction of bone by the infection.

We are certain that there are indications for resection of septic knee joints in civilian practice. These may occur following blood-borne suppurative arthritis, suppurative arthritis resulting from extension from a nearby infected wound or following direct trauma to the joint. The procedure is valuable particularly in joints destroyed by sepsis and complicated by a flexion contracture.

I appreciate Dr. Macey's discussion and particularly his agreement with the principles outlined in my paper. I sincerely hope that there will be a civilian application of the experience in suppurative arthritis here outlined.

CONSERVATIVE TREATMENT OF SEMILUNAR CARTILAGE INJURIES OF THE KNEE JOINT*

EVALUATION OF END RESULTS OVER A TEN-YEAR PERIOD

NELSON J. HOWARD, M.D.
San Francisco, California

THE conservative non-operative treatment of semilunar cartilage injuries of the knee joint is by no means a new concept. The prolonged struggle in England between the orthopedic surgeons and the lay "bone setters" bears evidence of the conflict. Sir Robert Jones, Bristow and McMurray have compiled excellent clinical descriptions of injuries to the semilunar cartilages of the knee proved by operative removal of the cartilages. The manipulative measures for reduction of displaced cartilages and the effectiveness of prolonged skin traction in overcoming locking of the knee joint are well known. Numerous writers advise such measures as first treatment, adding as a warning, that success cannot be assured, while Watson-Jones[1] is of the opinion that "non-operative treatment, with its uncertainty, is no less time consuming and incapacitating than operative treatment, which is certain."

Industrial injuries of the knee joint, with the control of the patient offered the surgeon, the hospital facilities offered the patient, and the prompt reporting back of the patient if treatment is inefficient and unsatisfactory, or the condition recurrent, thus preventing the worker from returning to his job in a normal manner, seems to provide an ideal field in which to test the effectiveness of conservative non-operative treatment of semilunar cartilage injuries. That treatment might well be followed in some instances by perfectly satisfactory end results, was strongly indicated by the experiments of Donald King.[2] King showed that in dogs, a torn meniscus can heal by fibrous tissue if the tear communicates with synovial membrane laterally, or if partly torn from its peripheral attachment. He found that in a complete transverse or oblique tear, the intervening space fills with connective tissue, which becomes quite firm in three weeks time, thus suggesting the length of time necessary for complete immobilization of the joint. King also found that a longitudinal bucket-handle type of lesion entirely within the cartilaginous portion of the meniscus showed no evidence of repair. S. Alwyn-Smith[3] illustrates by photographic examples, healing and partial healing in removed human semilunar cartilages. Many authors, particularly the German and Italian had shown that in humans, after complete excision of the semilunar cartilage, a fibrous reformation approximating in gross appearance the normal, took place.[2] Other observers had produced experimental regeneration of excised semilunar cartilages in animals.

Over a ten-year period, 299 injuries about the knee joint, exclusive of fractures, were encountered. By far, the major portion, eighty-four, were strains and sprains of the joint ligaments, often accompanied by joint effusions, serous or bloody. Serous synovitis following sprain occurred in twenty-one instances, and hemarthrosis was observed in thirty-nine patients. While severe internal lateral ligament injuries occurred in sixteen cases, external lateral ligament injuries were found in only two patients. Cruciate ligament injury was discovered twice. Osteochondromatosis, osteochrondritis dissecans and joint mice were each encountered in single instances. It is of interest to note that prepatellar traumatic bursitis was present in forty-five patients, superficial infrapatellar bursitis in eighteen patients and deep subtendinous infrapatellar bursitis in two individuals. One atypical periarticular bursa was found and three patients had a cyst of the external semilunar cartilage. Among these injuries were fifty-six cases diagnosed as having semilunar cartilage injuries after a careful study of the history of the mechanism of the injury and the physical signs presented by the patient.

Of the fifty-six patients, forty-nine were male and seven female. (Table I.) The internal semilunar cartilage was affected in forty-seven cases and the external meniscus in nine instances.

* From Stanford Medical School, San Francisco, Calif.

The right and left knees were involved equally. Tenderness over the affected cartilage was the most frequent sign of value and was constant in varying degrees of flexion and extension of the knee (96 per cent). Such tenderness was definitely distinguished from that of sprain or tear of the lateral ligament which is most apt to be near the bony origin of the lateral ligament rather than in the femoral tibial sulcus overlying the cartilage. Again, the tenderness overlying an injured cartilage is not associated with pain on abduction of the extended knee away from the side of the lesion, but is apt to be accompanied by pain on adduction of the knee (particularly if locked in the last few degrees of extension) toward the affected cartilage.

TABLE I
FIFTY-SIX SEMILUNAR CARTILAGE INJURIES

	No.	Per Cent
Males	49	87
Females	7	13
Internal semilunar cartilage	47	84
External semilunar cartilage	9	15

A history of locking of the knee at the onset of injury was viewed with suspicion if not shown at the time of physical examination. An extensive effusion ballooning out the joint may prevent full extension of the knee. After aspirating the joint fluid, serous or bloody, one can quickly detect the presence of true locking. Locking was found on physical examination in forty-two cases or 75 per cent of those diagnosed as having semilunar cartilage injuries. (Table II.) Joint fluid accompanied the cartilage tenderness or locking in thirty-five patients (62 per cent). One instance of accompanying lateral ligament sprain and one apparent anterior cruciate ligament sprain occurred in these semilunar cartilage injuries. One patient suffered a simultaneous longitudinal fracture of the patella. These three patients were treated conservatively with satisfactory end results.

Nine patients gave histories of previous serious knee joint injuries with locking of the joint and disability prior to the injuries for which they came to our attention. In four such cases, it was found necessary to remove the cartilage by operation. Two patients of this group were treated without operation with satisfactory end results; one patient was treated conservatively, and when last seen a year after his return to work, he still complained of slight discomfort in the knee, but he had no fluid or locking during this time. Two patients with definite semilunar cartilage injuries and a history of previous injuries with locking of the knee while working for other employers, were turned down for treatment by insurance carriers, and consequently were lost for treatment and follow-up study.

TABLE II
MAJOR PHYSICAL SIGNS

	No.	Per Cent
Joint fluid	35	62
Locking of joint	42	75
Tenderness over the injured cartilage	54	96
Right cartilage	28	50
Left cartilage	28	50

TREATMENT

In the beginning, our treatment of the patient with semilunar cartilage injury consisted of reduction of the cartilage by manipulative measures, if possible, aspiration of joint fluid if the joint was tense and distended, application of a very heavy voluminous sheet wadding bandage, held by elastic bandaging, and the use of crutches or a cane, advising the patient at the same time to be recumbent as much as possible. In those patients in whom reduction of the slipped meniscus could not be carried out by manipulation were placed in traction in bed. It soon became evident that patients so treated absorbed the joint effusion much quicker, the cartilage was less likely to displace after reduction and their convalescence less prolonged. At first, sheet wadding and elastic bandages were used as the only immobilization after traction reduction. This had to be reapplied constantly. A circular unpadded plaster splint, reaching from the ankle to the upper third of the thigh, was found to be the most satisfactory form of immobilization. Slipping and shifting of the splint was prevented by adhesive strips the length of the leg beneath the cast, turned back and incorporated into the plaster above the malleoli.

The method used in the last seven years is as

follows: In fresh semilunar cartilage injuries, hospitalization with Bucks adhesive traction is instituted at once. Manipulative reduction of displaced cartilage is attempted. If unsuccessful, the reduction is left to constant skin traction. A weight of 8 to 10 pounds is sufficient.

TABLE III

Conservative treatment	82%
Operative treatment (10 cases)	18%
Previous injury with locking of knee	9 cases
Previous injury with recurrence—operation	4 cases
Previous injury with satisfactory conservative treatment	2 cases
Previous injury with conservative treatment with slight difficulty	1 case
Treatment denied by Ins. Co. because of prior injury	2 cases

The adhesive strips run to just below the knee. The malleoli are well padded with soft flannel bandage and felt against pressure of the adhesive strips, and bias cut muslin or flannel is used as a wrapping to maintain contact of skin and adhesive tape. If an effusion is present, such bed rest and traction cause suprisingly prompt disappearance of the effusion, if the meniscus is reduced either by traction of by manipulation. The thirty-seven cases in which traction was used, averaged 7.2 days of traction, ranging from three to thirteen days in individual cases. Aspiration was necessary in five patients, one individual requiring aspiration twice. Recurrence after becoming ambulatory took place in seven patients to be followed by operative removal of the cartilage. In three patients, reduction by manual manipulative means and by traction was unsuccessful. These patients were operated upon. An occasional unreduced cartilage may be manipulated under spinal anesthesia successfully; if reduction fails, immediate operation is performed.

Following reduction of the cartilage and return of full voluntary extension under the influence of traction, provided the fluid has disappeared, the adhesive suspension sling and plaster of paris circular splint is applied. The patient becomes ambulatory and the cast is removed in from twelve to fifteen days. The period of splint immobilization in these patients averaged fifteen days, and in individual cases from eight to thirty-three days.

All patients are instructed in quadriceps exercises from the beginning, and these exercises are enforced by the physician and the nursing staff. When ambulatory in the circular splint, leg raising and tip-toe standing exercises are encouraged. Upon removal of the splint, an elastic knee bandage is provided, and exercises for regaining movement and maintaining muscular tone and development are prescribed, if, in two weeks, after removal of the splint, progress in motion and muscular development does not seem satisfactory, exercise, heat and massage are given under the direct supervision of our physiotherapist. Stationary bicycle riding and leg raising with attached weights, as well as previously prescribed exercises, are then carried out.

TABLE IV

	Days
Days from injury to initial treatment:	
Average (56)	10.8
Operated cases (10)	30.0
Unoperated cases (46)	6.7
20 days or more—(injury to treatment)	11 cases
Delayed treatment—6 of 10 operations	

RESULTS

The average limbering up period of the non-operated patients after removal of the splint was seventeen days. Naturally, operative cases require a much longer time. In non-operative cases, the period of disability before returning to and remaining at work averaged thirty-seven days. (Table v.) The average days of disability for all cases was sixty-two days, and the average time away from work for the ten operated patients was 152.7 days. Patients were kept under observation until no doubt of the success of treatment remained. The period of observation in the non-operated cases averaged 72.2 days, in the group as a whole, 104 days, and in the ten operated cases, the average days of observation was 223.

Some explanation is necessary in regard to this long disability period of the operated patients. It is of more than casual interest that the average number of days for all patients from date of injury to the initiation of proper treatment was 10.8 days. (Table IV.) In those patients treated conservatively, this period averaged 6.7 days, while in those cases requiring operation, the average number of days from injury to initiation of definite treatment was thirty days, and in individual cases from the day of injury to ninety days after the injury. Of eleven patients reporting for treatment twenty or more days after injury, six required operation. Two who had previously experienced

locking and fluid with prior injuries reported promptly and required operation; six patients reported with recurrence of the meniscus locking after becoming ambulatory under conservative treatment and they were subsequently operated upon.

TABLE V

	Disability
Unoperated cases (46)	37 days
Total patients—average (56 cases)	62 days
Operated cases (10)	152.7 days
	Observation
Unoperated cases (46)	72 days
Total patients—average (56 cases)	104 days
Operated cases (10)	223 days

In one individual, in whom an accurate diagnosis could not be made, constant recurrence of knee joint effusion took place, After 198 days, he was operated upon and an injured cartilage found with a marked synovitis. His period of disability was 300 days. He regained full motion and a stable knee but he continued to have atrophy of thigh and calf.

One patient illustrates an error in surgical judgment. Even though local heat and a hot tender knee was observed prior to operation, the patient had definite evidence of semilunar cartilage injury with locking, fluid and a tender cartilage. Reduction of the locking was accomplished by traction with recurrence of fluid after removal of the splint. After 158 days of observation, the patient had not improved. The knee was still swollen and hot. No focus of infection could be found, the leukocyte found was not elevated, although the sedimentation time was rapid. Operation was carried out, the semilunar cartilage detached in its anterior portion with marked pannus formation from the anterior cruciate beyond the cartilage discovered. On removal of the pannus and meniscus, fragmented, raised articular cartilage of the tibia was found and removed. Convalescense was slow. Local heat, swelling and low grade fever continued for some weeks after operation. A fibrous ankylosis resulted with 20 degrees lack of extension, and only 36 degrees of active flexion, with pain and swelling of the knee on prolonged active use of the leg. This patient returned to another form of work in 330 days and was observed over a 540-day period before being discharged.

Those patients treated successfully by traction, reduction of the meniscus and by splinting, represent 82 per cent, forty-six of the series, 18 per cent or ten of the series requiring operation. (Table III.) Residual atrophy of the thigh or calf, or impairment of motion of the knee joint at the end of the period of observation of individual cases was surprisingly infrequent (Table VI) and is an objective measurement of the relative success of the method of therapy. Since the patients in this series were employed by stable, long-standing industrial firms not in war plants, and the patients themselves settled citizens not migrant workers, recurrence of symptoms or exacerbation of difficulty by new injury would have come to our notice.

TABLE VI

Remaining Measured Atrophy:	
Thigh	10 cases
Calf	9 cases
Operated cases	7 cases
Conservative treatment	5 cases
Remaining Limitation of Motion:	
Extension	5 cases
Flexion	7 cases
Operated cases	5 cases
Conservative treatment	5 cases

COMMENT

Regeneration of fibrous structures resembling the semilunar cartilage has been reported in humans after complete removal of the meniscus. Animal experiments have confirmed the fact that such regeneration may recur. Kings experiments show that injuries involving the fibrous portion of the meniscus or transverse or oblique complete tears of the cartilage may be well healed by ingrowth of fibrous tissue, and that true "bucket-handle" fractures of the meniscus involving the cartilaginous portions do not heal. One has no means by which one can diagnose by clinical signs the presence of a "bucket-handle" injury of the cartilage. "Bucket-handle" injuries can be truly discovered only on operative removal of the meniscus.

Long ago Sir Robert Jones emphasized the longitudinal split as the common type of meniscus lesion. A recent writer[4] states that Sir Robert Jones was unable to find such tears of the meniscus in 10 per cent of his operated cases, while Bristow, in careful compilation of injuries, was unable to find such cartilage tears in 30 per cent of the cases he operated upon. Harry Platt[5] found that 33 per cent of patients who were operated upon for previously diagnosed semilunar cartilage injuries showed no

evidence of fracture, and he believed that most cartilages of this group were of the "hypermobile" type. Platt showed that in the cartilages with fracture, 93 per cent had longitudinal tears, and a little more than half of these cases were of the "bucket-handle" type.

It is possible that some few or many cartilage injuries of the longitudinal type might occur near the transition from joint ligament and capsule to the fibrocartilage of the meniscus. If so, one could expect complete healing if the torn surfaces were approximated in the reduction and the joint immobilized. It is not likely that a sufficient wide tear would take place with subsequent healing without immobilization to account for the high percentage of hypermotile cartilages found by Bristow and by Platt. Most of the splits of the anterior and posterior horn run directly into areas of the meniscus which are in direct continuity to the synovial fringes, the infrapatellar fat pad and to the anterior and posterior fibrous horns of the cartilages themselves, all of which would furnish blood supply for the ingrowth of new fibrous tissue for healing, once the cartilage was reduced to a semblance of normal contours and the limb immobilized.

From the tables presented in this study, it is evident that attempts at conservative treatment of semilunar cartilage injuries of the knee joint are definitely worth the effort of the physician. Rapid response to the treatment outlined is the rule. Recurrence or failure of therapy calls for immediate operative removal of the meniscus. The earlier rest, traction and splinting are enforced, the greater are the chances of recovery under conservative treatment, and conversely, the longer the delay in such treatment, the more certain will be the necessity for operation.

CONCLUSION

1. In a small carefully studied series of traumatic knee joint lesions, diagnosed as semilunar cartilage injuries, 82 per cent (forty-six patients) were successfully treated by conservative means; 18 per cent (ten patients) were operated upon.

2. The treatment advised is immediate hospitalization, manipulative or constant adhesive traction reduction of the locked joint, aspiration of the joint, if necessary, and immobilization of the injured knee by circular plaster splint.

3. It is shown that the earlier complete rest of of injured joint is enforced, the more likely is the success of the conservative treatment, and conversely, the longer the delay in instituting treatment, the more certain will operative intervention be required.

4. Pathologic, anatomic studies of the injured meniscus in patients and experimental work on animals reported by many observers provide a sound logical basis for the success of conservative therapy.

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DISCUSSION

George J. Curry (Flint, Mich.): Flint is an industrial city with 60,000 factory employees, many of whom are subjected to knee joint trauma. Internal derangements of the knee joint occur, and over the past ten years a large number have been managed. Satisfactory statistics on follow-up care are impossible because of changing patient personnel.

The present plan of management by my associates and myself may be summarized as follows:

1. Such knee joint injuries, if seen fresh, pointing to an internal derangement, presumably diagnosed as a probable disrupted meniscus, are manipulated by gentle manual traction under anesthesia to obtain extension comparable to the degree of the unaffected side. This would indicate a probable restoration of the knee joint continuity and possible replacement of the cartilage. Aspiration is done in cases with marked effusion or hemarthrosis. Immobilization in plaster of paris for several weeks follows. This enables early full weight-bearing. A course of quadriceps exercises is most essential. Following removal of the plaster of paris cast, a second evaluation is made. If there is a recurrence of the disability or positive physical signs, surgical intervention is indicated.

2. All chronic cases of recurrent locking, continuous pain, instability, effusion and so forth, either in combination or alone, are accepted for exploratory arthrotomy and probable excision of the affected

meniscus. We believe that conservative management in this type of case obviously is of little or no value.

3. There is a group of cases presenting minimum, mild, localized pain over the joint with associated tenderness and "clicking" sensations. There is no associated instability, effusion or quadriceps degeneration. This type of case, we believe, indicates a possible partial dislocation or minimal cartilage tear. Quadriceps function and stability are good. These cases are kept under observation and the management is conservative and expectant. If disabling symptoms occur, surgical intervention is strongly considered.

The internal meniscus is damaged more frequently—85 per cent in our cases. The incidence of multiple lesions is relatively high and it is frequently necessary to explore the entire joint. The patient must be thoroughly trained in quadriceps exercises prior to operation.

The larger percentage of all meniscus injuries over the past ten years have required operative management. However, we believe that conservative management of the smaller group is a justifiable plan.

The convalescent period in the operated cases averages much less than five months. Exploratory operation in the cases of questionable diagnosis seems logical.

The statistics presented by Dr. Howard derived from a close follow-up on the conservative management of damaged menisci are very interesting. They serve as a stimulus to some of us whose experience is the reverse.

Thomas B. Quigley (Boston, Mass.): The experience of the Harvard Athletic Association is in agreement with the experience of Dr. Howard, because since 1932, under Dr. Thorndike's leadership, a conservative policy has been followed with regard to knee injuries.

We agree with the speaker and the previous discusser in principle, but we differ somewhat in the details of the therapy. This problem of knee injuries can be considered, at least from certain points of view, as a local problem; what might be right and proper treatment for a shipfitter is not always necessarily applicable to an undergraduate athlete.

Our program has been two-fold: (1) prevention of injury and (2) therapy. The preventive aspects have been discussed before this Association in the past by Dr. Thorndike and very briefly consist of a survey of all old knee joint injuries in athletes who indulge in contact sports, and preventive taping.

As to therapy, traction is out of the question for these undergraduate athletes. Modern college life is a chain reaction it seems, and if one loses even a week, one is likely not to graduate. Therefore, our patients are almost always ambulatory, the keynote of treatment consisting of compression dressings, careful physical therapy, which is principally active exercise and rest of the joint on crutches. The crutches do not disable the undergraduate student from doing his job, which is to study. Actually, they make him study more because it is too much trouble to go to the movies on crutches.

W. McGaw (Cleveland, Ohio): This paper and the discussions have interested me very much. While in the Southwest Pacific during the war we had a large number of knee cases at one time, some acute and some recurrent. We became interested in the use of pneumograms in helping us in the accurate diagnosis and in the treatment.

While we were overseas, we saw some 500 cases that were studied with pneumography. Of this group, 180, or approximately 35 per cent, were operated upon. The rest of them were treated conservatively. A few of these however, were sent back to the States if we believed we could not rehabilitate them overseas.

I think we all agree that in knee injuries, the treatment rests so much on an accurate diagnosis. We all realize that the contusions will heal conservatively, sprains will heal, torn ligaments will heal if they are protected, tears in the synovia will heal. The difficulty arises in cases that do not heal so readily and adequately.

We have believed, and agree perfectly with Dr. Howard and the discussers, that a meniscus injury will heal if it occurs near the coronary ligament or its attachment to the capsule. However, we also believe that if there is a dislocation, multiple tearing and shredding of the menisci, or a history of many previous injuries, these cases should be treated the sooner the better by surgery. We have believed that with the use of pneumograms we could diagnose many of these cases early when first seen. We know that we could diagnose single and bilateral tears, and dislocations; we could tell in many cases whether the tear was near the periphery. I make a plea for early accurate diagnoses of all injuries of the knee. The treatment should be planned on a specific diagnosis. It is believed the conservative treatment is the proper treatment in about 60 per cent of all knee injuries.

Joseph M. Meherin (San Francisco, Calif.): I think for a number of years many of us have been very hesitant to operate on the older age group with injuries to the semilunar cartilages. I think Dr. Howard's paper brings out something that we perhaps have not clearly realized. Initial injuries in this older group have responded very well to conservative treatment.

The time relation between the initial injury and the institution of treatment is extremely important. Dr. Howard has given me the privilege of reading his paper and I would say that he was too honest. The period of 152 days is, as is always in honest statistics, a little too high. Very often, in the

other type of statistics, the periods of disability are much too low. In reviewing these cases, one sees that there was one case with a disability of 300 days and another with 332 days. If those are included, you can understand a period of average disability of 152 days much more readily.

I would like to bring out again something that has been stressed time after time but that I think we neglect, namely, in puzzling cases we can very often get useful facts by examining the patient's knee while the patient is standing.

I would like to ask Dr. McGaw if he would take one minute or two to tell us a little more about days of disability, how many of those patients were sent back to the States.

President Carothers: I am sorry, Dr. Meherin, but he may not discuss twice.

Dr. Meherin: I see. Well, those are answers that are very difficult to find out. I have tried to find out a good deal about them while I was in the service and, of course, they are not actually available.

Augustus Thorndike (Boston, Mass.): Age has a great deal to do with the reparative powers of the meniscus. Dr. Quigley was speaking of a young and virile group. Dr. McGaw did likewise. But when you talk about the industrial case you are talking of an age group that is in relatively poor physical condition as compared to the soldier or the athlete.

I find that much time is lost, as I look around among civilians I see treated, in the fact that doctors and patients allow effusions to accumulate. We found that the shortening of the time of convalescence was due to controlling the effusion. We rarely see an effusion in a knee today. We apply cold, ice water, for a period of one-half hour, and a sponge-rubber compression on sheet wadding after that, and it is perfectly extraordinary how well it controls the effusion.

It is rarely that we have an arthrotomy, and as Dr. Quigley pointed out, we check up on all entering freshmen to inquire if they had an injury or sprain before they enter college. It is our experience that meniscus injuries are rare with the first sprain; that it is the subsequent sprain to a weakened ligament that damages the cartilage or causes the cartilage to be damaged.

We do not immobilize in a cast and we apply physical therapy as soon as we are sure that the possibility of a hemorrhage being started by massage is over, on the third day, and in the weight-bearing joint; of course, we keep them on crutches for that period. But we have had great success with an average time of sixteen days in our knees before they go back to playing football.

The industrial cases pointed out by Dr. Howard were ten days before they got to him. That is ten strikes on him already. It is too bad. It delays the period of recovery a great deal. If our industrial injuries could be put back to work, there would be a great saving to all if we could do it as fast as we can with the athlete. I enter a plea for prompt, early treatment of these cases and control of effusion, when possible.

Nelson J. Howard (closing): I want to thank Dr. Curry not only for his kindness in discussing the paper but also for his kindness and his charity at the same time in his expressed opinions. I rather have the feeling that he is not quite so sure that the conservative treatment will give the results that I have shown to you today.

I do believe, first of all, that the immediate treatment of the injured individual has a great deal to do with the success of the treatment. There are always going to be those "bucket-handle" fractures which cannot be reduced or those fractures of the cartilage which are in the purely fibrocartilaginous portion of the miniscus, which will not heal.

I want to emphasize that we have the opinion that if the conservative treatment is not promptly adequate in your clinical judgment, that patient should be operated on without further waste of time. This is not a plea against operation, but it is a plea for operation in only those cases that need it.

Dr. Quigley was very kind in bringing up the statistics from Harvard among the amateur athletes. I think that Harvard is particularly fortunate in this country in having a carefully controlled, medically controlled, group of athletes. That is not by any means the rule of the country and I believe that the amateur at least is like a race horse: He has a short life of intense activity and a long life, oftentimes, of crippling disability or discomfort from it. Many of the men in the audience can remember that from their college days. I have seen a man with a dislocated shoulder taken out of a football game, his shoulder incompletely reduced—you could see that it was incompletely reduced from the stand. He would hold it as if he had a luxatio erecta. That patient would be sent right back into the football game to have the shoulder redislocated on the next play.

I have not had any experience with pneumograms of the knee joint. A good many years ago, when I was first considering the problem of using pneumograms on the knee joint, I happened to run into five successive references within two weeks' time on fatalities from air embolism, so that my enthusiasm was discouraged and I did not begin the use of them. I am glad to know that Dr. McGaw has had success with them and I would like to know more about it from him later.

Dr. Meherin asked about the age incidence of these patients. Dr. Meherin and I have been associated with each other in San Francisco for a time, and Dr. Meherin himself took care of a few of these patients that I have shown you. When he first

asked me this question, I went back and tabulated the age groups by decades, and I found that by far, the majority of the injured individuals were between thirty and forty and forty and fifty years of age. There were two people in their eighth decade still working, receiving these injured as industrial injuries, over seventy years of age. One of them responded beautifully to conservative treatment; the other had to be operated on and his work disability was only sixty days before going back to full work.

Dr. Meherin mentioned the disparity between the total period of disability in operative cases and the short period of disability for the conservatively treated cases. That might leave you with a misapprehension. There were two cases of prolonged disability which were operated upon, which gave rise to this poor statistical result. One was an individual who had a chronic and recurring effusion of the knee joint. It was extremely difficult to diagnose the true lesion. He was an inebriate bartender who fell down a flight of stairs. He came to us late with an effusion. It was difficult to determine whether he had a semilunar cartilage injury. At no time did he have a history of locking or, on physical examination, locking of the knee joint.

Finally, after 180 days of constant recurring effusion, in spite of bed rest, traction and aspiration, his knee joint was explored. A torn semilunar cartilage was found—without a history of locking, without physical signs of locking—and his total disability was 300 days.

The second one with prolonged disability was a mistake in surgical judgment. That man came to us rather late with a fresh injury, but rather late after the injury. He had a hot joint. He had definite tenderness and locking. He had no fever, he had no leukocytosis, but he had, very definitely, a markedly elevated sedimentation rate. The joint locking responded to adhesive traction. The effusion disappeared within thirteen days—rather prolonged. He was placed in a working splint and was allowed to walk for three weeks. On removal of the splint, locking and recurrence of a slipped cartilage took place, and effusion came on again, so he was operated upon, in spite of the fact that he had a warm joint, and at operation, a pannus was found running from the cruciate ligament to a split in the anterior horn of the semilunar cartilage. When the pannus was removed, it was seen that the joint cartilage beneath the semilunar cartilage had been fragmented and raised 1 or 2 mm.

Another mistake was made when this elevated joint cartilage was excised. This patient has a rather stormy postoperative course but a prolonged one; he had low-grade fever, marked effusion of his joint, he ended up with a stiff, ankylosed and painful joint, with only 30 degrees of motion. He had to change his occupation, and he did not go back to work for 330 days and was kept under observation for some 500 days.

With those two exceptions, all of the operated cases, actual fractures of the semilunar cartilage that were found, had a period of disability before going back to heavy work ranging from only sixty to ninety days.

I am sorry that I do not have time to discuss the other remarks.

MULTIPLE MUSCLE SUBSTITUTION FOR CORRECTION OF FACIAL PARALYSIS

WM. MILTON ADAMS, M.D.
Memphis, Tennessee

FACIAL paralysis presents not only a disabling and disfiguring deformity, but a most difficult problem from the standpoint of satisfactory correction. One should not be content merely to give support to the affected muscles; it is also necessary to restore as much motion as possible to the entire paralyzed side of the face. This may tax to the limit the ability of the most highly skilled surgeon.

In paralysis incident to simple severance of the facial nerve, regeneration may follow suture of the two ends. In the event the ends of the nerve have probably been bruised, permanent suture is best delayed until the eighteenth to the twenty-first day following injury, since one can then determine the exact extent of the damage to the nerve beyond the point of severance. In the presence of a small gap in the nerve, a free graft may often be utilized for repair. A defect in that part which lies within the facial bony canal lends itself well to the nerve graft procedure described by Bunnell in 1927. If neither of these methods is feasible, a satisfactory result may occasionally be obtained by an anastomosis of the distal end of the facial nerve to one of the other cranial nerves, usually the eleventh.

For extensive injury of the nerve or permanent paralysis, either fascial strips or muscle pedicle grafts may be utilized. By far the most popular technic has been the use of fascial strips attached to the temporalis fascia or muscle, or both, the strips being carried down to give support to the most noticeably sagging areas of the face. There are two reasons for the popularity of this procedure: the technic is simple and the improvement is immediate. No motion is obtained, however, or at least only a negligible amount. Neal Owens has utilized the masseter muscle in preference to the temporalis, attaching the fascial strips to the lips and corner of the mouth and looping them through the body of the masseter muscle. He has found that this not only provides support, but the results are definitely better with respect to motion about the corner of the mouth than following the use of the temporalis muscle.

Muscle transplantation provides support equal to that of fascial strips and, in addition, permits voluntary motion. In some cases, moreover, fascial strips tend to relax, with a consequent return of the sagging of the muscles, whereas following the transplantation of muscles, the tone improves as reeducation of the transplants is continued.

The principle of muscle substitution seems to have been first employed by Lexer in 1867, who transplanted a pedicle of the masseter muscle to the corner of the mouth, to give motion in this region of the face. A number of other surgeons have since transplanted the masseter muscle by one technic or another for the same purpose. Gillies and Sheehan have each employed the temporalis alone for restoring motion to the entire side of the face. The muscle is detached at its origin above, divided into strips and brought down; one strip is attached in the upper eyelid, one in the lower lid, one in the supra-orbital region and one or more around the angle of the mouth. When the temporalis muscle is transplanted to the region of the mouth, however, its pull is largely upward and only slightly backward. This muscle is most suitable for restoring motion and giving support to the eyelids, providing, as it does, a slightly upward pull.

In paralysis of the facial nerve, there is a loss of function of eleven major and nine minor muscles of expression. One cannot, therefore, expect one muscle to carry out the work of the entire group. Obviously, the larger the number of different muscles which can be brought into play, the better the function one will be able to restore to the paralyzed area. By substituting muscles from different locations, muscle pull in various directions may be provided, thus insuring a more nearly normal direction of motion.

The masseter muscle, because of its location, is most suitable for reanimating the corner of the mouth and the lower part of the paralyzed

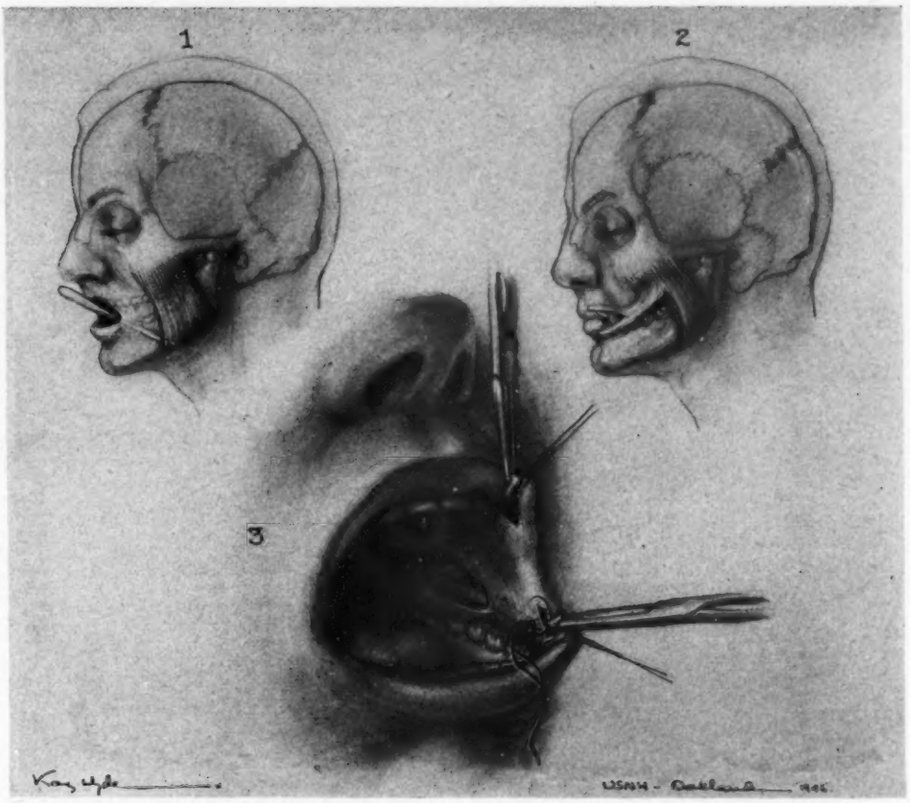


FIG. 1. Transplantation of the masseter muscle to the region about the angle of the mouth. (1) Freeing the masseter muscle from its insertion along the lower border of the mandible through an incision in the buccal mucosa. (2) The masseter muscle flap divided at its distal end and swung anteriorly to the region about the mouth. (3) The muscle flap being threaded through the formed tunnel beneath the mucous membrane of the mouth into the body of the obicularis oris muscle of the upper and lower lip. The ends of the flaps are sutured as near the midline of the lips as possible. A third suture is placed at the lateral border of the obicularis oris muscle where it conjoins with the risorius to bring out the nasolabial expression line. (See footnote p. 664)

face. By transplanting the end of the insertion of the muscle at the lower border of the mandible, one is less likely to disturb the nerve supply, the pull is in the desired direction, being slightly upward and backward, function is thus more active and the effect is more natural than if the temporalis muscle were utilized.

The operation is best performed under local anesthesia, in that it is desirable to have the patient's assistance in contracting the muscle from time to time during the operation. Unless the masseter muscle is unusually small or is attached posteriorly on the body of the mandible, the intra-oral approach is used. By having the patient clinch the teeth, the body of the muscle is brought forward against the buccal mucosa. On incising the mucosa along the anterior margin of the muscle, one immediately encounters the muscle and may readily deliver it through the incision. (Fig. 1.) If the muscle is attached more posteriorly on the mandible, an extra-oral approach along the lower border of the mandible is preferable.

The pedicle is dissected up from the lower margin of the mandible and the fibers are separated longitudinally by gentle finger dissection. The muscle should be divided only for a sufficient distance to form a flap of proper length, as the higher the dissection is carried, the greater the danger of impairing the nerve supply. A small incision is next made in the mucous membrane of both the upper and lower lips, just lateral to the midline at or near the vermilion border. Through each of these incisions a tunnel is formed through the body of the orbicularis oris muscle, the tunnels meeting at the corner of the mouth. The

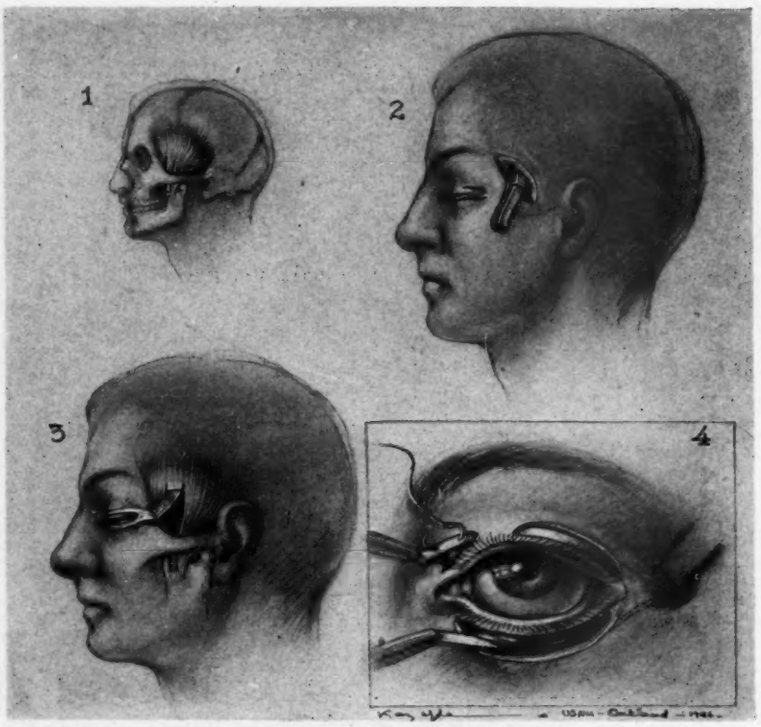


FIG. 2. Transplantation of a flap of the temporalis muscle to the eyelids. (1) The location and amount of temporalis muscle used to form a flap; (2) the freed temporalis muscle flap with overlying fascia intact; (3) the overlying fascia reflected down from the body of the muscle to give needed length to reach the inner canthal region and divided to give a strip for both the upper and lower eyelid; (4) the flaps threaded through the eyelids and the ends sutured in the inner canthal region.

tunnel is then continued backward from this point to the masseter region.

The distal end of the pedicle is now split in half for ½ to ¾ inch, and the upper and lower halves are delivered through the tunnels of the upper and lower lips, respectively, and attached to the muscle. A third suture is placed in the fork of the pedicle, which is just lateral to the corner of the mouth; this aids in forming the nasolabial expression line when the patient contracts the muscle.

Within two months after the operation, the patient is able, by clinching the teeth, to develop fairly satisfactory control of the pedicle, with motion in the corner of the mouth and surrounding region. Further improvement may be expected for an indefinite period, as long as the patient persists in daily exercise of the muscle.

The temporalis muscle is utilized in a similar manner to restore support and function to the paralyzed upper and lower eyelids. Again, the end of the insertion of the muscle is transplanted. A vertical incision 1½ inches in length is made inside the hairline and just above the zygomatic arch, usually anterior to the temporal artery. (Fig. 2.) The muscle flap, which should be about ½ inch wide, is dissected up from the anterior portion of the coronoid process of the mandible. To sever the attachment from the coronoid process, long slender scissors with an acute angulation at the ends of the blades are used. The overlying fascia of the temporalis muscle is left attached to the flap and, in order to lengthen the flap sufficiently to reach the inner canthal region, the fasica is reflected downward. Here, also, in forming the pedicle, the fibers are separated longitudinally with gentle blunt dissection to interfere as little as possible with the nerve supply.

A tunnel is created through the subcutaneous tissues from the temporal incision to the outer canthal region, thence through both eyelids to the inner canthal region. The distal end of the flap is split for a distance of 1 to 1½ inches,

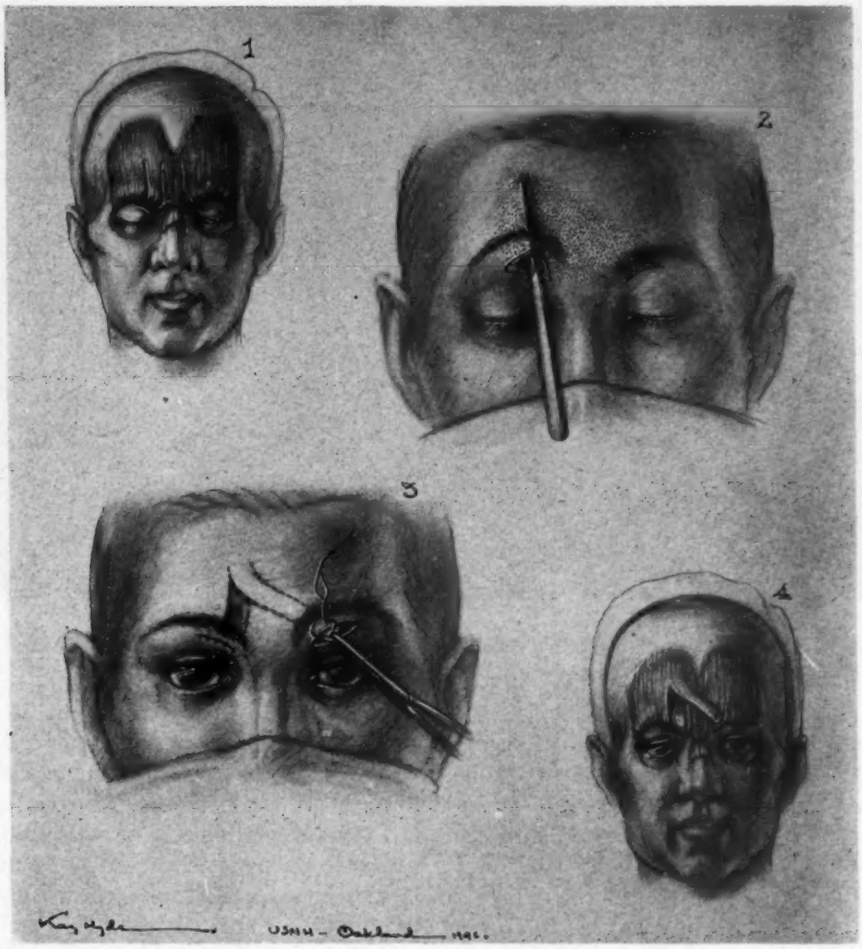
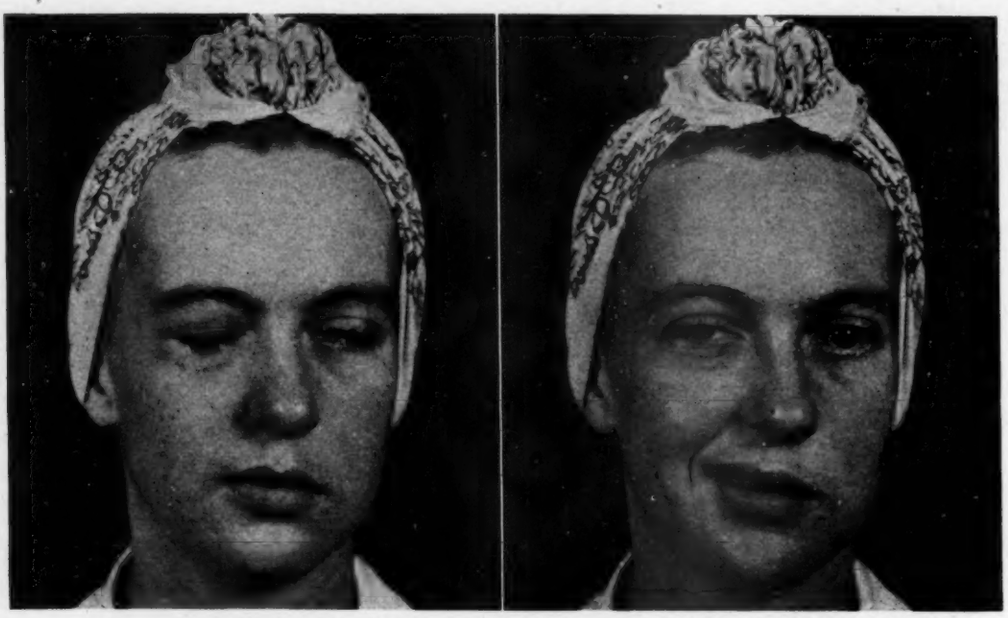


Fig. 3. The transplantation of the frontalis flap to the opposite eyebrow region. (1) and (2) show two small incisions at the inner border of the eyebrow just below the hairline and the area of skin of the central portion of the forehead undermined at the donor site of the frontalis flap. (3) and (4) show the flap being swung over to its new location and the point of fixation of the distal end.

and one-half is threaded through each of these tunnels, brought together and attached to the inner canthal ligamentous tissue. A malleable dissecting probe is useful in delivering the flap through the tunnel, a thread being tied around the ends of the flap and passed through the eye of the probe. One should be careful with respect to the tension on the flap; the tension should be sufficient to permit closure of the lid on relaxation of the levator, yet not enough to prevent raising of the lid on contracture of this muscle. The tension may be tested by having the patient open and close the lids before the transplant is permanently sutured in place.

The immediate effect of this procedure is dramatic, in that the patient is able to open and close the lids at will as soon as the muscle flap is attached to the inner canthal ligament. It is my impression that this is not a result of the contracture of the muscle pedicle; rather, the tension of the flaps automatically draws the lids together upon relaxation of the levator palpebral and orbicularis muscles. The ability to open and close the lids by contracture of the transplanted muscle is not acquired until two or three months later.

Some patients with facial paralysis have extremely active muscles of the brow and forehead, the brows being constantly raised and lowered. An active forehead on one side, in contrast to the blank immobility and drooping lid and brow of the paralyzed side, presents a conspicuous disfigurement. By transferring a muscle flap of the active frontalis to the muscle bed of the paralyzed eyebrow, attaching it just beyond the midline of the fore-



A B

FIG. 4. A, Case 1. Preoperative picture showing patient attempting to close eyes, muscles of expression relaxed; B, patient smiling showing asymmetry of the face.

head, one cannot only support and elevate the drooping brow, but can also restore some degree of upward motion in this area.

The frontalis muscle is transplanted through two incisions ½ inch in length at the inner border of each eyebrow, just below the hairline. (Fig. 3.) Through these incisions, the skin overlying the middle third of the forehead is completely undermined. An incision is made beneath the skin down to the periosteum in the midline of the forehead from the hairline to the glabella region. From this point, the medial ¼ or ½ inch of the frontalis muscle is severed at its lowest attachment and divided high enough to permit the distal end to be shifted across the midline into the opposite eyebrow region. In pedunculating the muscle, the fibers are separated vertically by blunt dissection. The pedicle is sutured into the body of the orbicularis occuli supercilia muscle with No. 0000 chromic catgut. Although the muscle pull is more or less obliquely upward near the midline of the forehead rather than vertical, the result is a distinct improvement over the previous deformity.

Approximately three months is required for restoration of function to this transplant, in contrast to the two months required for the same purpose following transplantation of the temporalis and masseter muscles to the eyelids and mouth. The rate of improvement and the end results are in direct proportion to the amount of exercise given the involved muscles.

Following all these procedures, an elastic pressure bandage is applied, to be worn for one week as a precaution against postoperative hemorrhage and excessive swelling of the tissues. Motion should not be attempted for eighteen to twenty-one days after operation. The patient is then instructed in the necessary movements and is encouraged to carry out the exercises faithfully every day, preferably before a mirror. Electric stimulation for a few minutes daily is useful as an aid in reeducation of the muscles.

In the transplantation of muscle flaps, several facts should be borne in mind, othewise the operation may be a failure. First, the flaps should be of sufficient size to insure the necessary strength and support to the paralyzed region. Second, the tension on the flaps should be ample to insure support and motion; on the other hand, undue stretching may lead to ischemia of the flaps. Likewise, too much angulation of the pedicle might interfere with its circulation. Third, we cannot too strongly emphasize the importance of care in separating the muscle fibers to form the flap in order not to disturb the nerve supply any more than necessary.

A B

Fig. 5. Case 1. Six months postoperative pictures. A, showing patient with eye almost closed and face bilaterally symmetrical in relaxed position; B, patient with eyes open, smiling slightly, showing the two sides of the face practically bilaterally symmetrical.

The results of these procedures, though far from perfect, are believed superior to those obtained by the usual supportive operations, either by fascial strips or the use of only one muscle. In each of the three transplants, the point of insertion of the muscle, rather than the point or origin, is pedunculated. Physiologically and mechanically, this insures the least interference with its circulation, nerve supply and direction of pull. Function improves as the patient re-educates the muscle and its tone increases. By continued efforts along this line, I am confident that we can give these patients consistently better results, bearing in mind the fact that muscle transplantation offers most to those with a definitely permanent paralysis.

CASE REPORTS

Case 1. B. F. S., female, aged twenty-one years, was observed in the Plastic Surgery Department of the U. S. Naval Hospital, Oakland, California, having been referred by the Neurosurgical Department following removal of a neurofibroma from the left eighth nerve. The tumor had been located beside the brain stem and had extended from the left temporal notch to the region of the medulla. The seventh nerve throughout this region had been sacrificed in its removal. The patient's convalescence was uneventful, though the left acoustic and facial nerves were permanently paralyzed. She wore a plastic support hooked into the corner of the mouth and attached around the left ear. (Figs. 4A and B.)

One month after removal of the neurofibroma, the first stage of the repair was carried out. A muscle flap about $\frac{3}{8}$ inch in diameter and $2\frac{1}{2}$ inches in length was obtained from the anterior third of the temporalis muscle by dissection from its insertion at the head of the coronoid process of the mandible. A tunnel was made beneath the skin over the malar bone and across the upper and lower eyelids, and the flap was passed through the tunnel to the outer corner of the eye. At this point, the distal 1 inch of the pedicle was split in half, and each end was sutured into the orbicularis occuli of the upper and lower lids near the mid-portion.

Three weeks following operation, it was observed that the patient slept with the eyelids closed. Between the fifth and sixth week, she was able partially to control the lids by clinching the teeth. Function gradually increased, and by the end of three months she was able to close the lids completely. This function was better when the patient was not fatigued. Although control of the lids was not entirely restored, the result was a material improvement. It is believed the outcome would have been more successful had the muscle flap been long enough to reach the inner canthal region. Function might still be improved by an elongation of the fascia to the inner canthus or by a simple fascial implant to support the lower lid.

Three weeks after the foregoing procedure, an intraoral incision was made along the anterior

A B

FIG. 6. Case II. A, preoperative photograph showing asymmetry of face in relaxed position. Drooping of wide left palpebral fissure, drooping left side of face and pulling of mouth to right. B, six months postoperative with face in normal relaxed position.

A B

FIG. 7. Case II. A, preoperative picture showing marked asymmetry of facial muscles of expression with patient trying desperately to close left eye; B, six months postoperative picture showing patient able to completely close left eye and retract left corner of mouth. Nasolabial fold definitely formed.

border of the masseter muscle, and a pedicle graft was dissected from its attachment at the lower border of the mandible. The distal end of the pedicle was split and transplanted into the upper and lower lips, according to the technic described. A light pressure bandage was applied and maintained over the area for one week. The patient was able to contract the corner of the mouth after five weeks.

To support and restore motion to the eyebrow region, a flap of the frontalis muscle on the right side, ½ inch in diameter, was detached from its insertion, swung across to the paralyzed left side and attached into the body of the orbicularis occuli

A B

Fig. 8. Case II. A, preoperative photographs showing marked asymmetry with the patient attempting to whistle; B, six months postoperative showing improvement with patient whistling. Marked improvement in asymmetry of entire face.

supercilia muscle and the lower portion of the frontalis. The first movement of the medial portion of the left eyebrow was observed two months later.

Unquestionably, this was a case of complete, permanent paralysis, without any possibility of a return of function except by surgical treatment. Circumstances prevented the patient from receiving more than one electrical treatment each week for the first two months. The function obtained by the three muscle transplantations was not entirely satisfactory (Figs. 5A and B), yet the improvement obtained must be accredited to the operations. At her last observation, the paralysis was not obvious and, when relaxed, the two sides of the face were almost symmetrical.

Case II. J. E. S., Corporal, U. S. M. C. R., aged twenty-two years, had received a through-and-through gunshot wound of the head during active duty. The bullet had entered just below the left eye, ranged through the left side of the face, through the inferior portion of the malar bone and the facial canal, and emerged through the left mastoid region. The wound had been débrided and drained in a field hospital. Roentgenograms had revealed a comminuted fracture of the left malar bone, the lateral wall of the left maxilla, the neck of the condyle of the mandible and the left mastoid process. There was no previous history of paralysis or sensory disturbance.

The patient was admitted to the Neurological Service of the U. S. Naval Hospital at Oakland, California, six weeks following the injury. He had a healed scar at the entrance of the bullet below the left eye, and another behind the left ear. Neurologic examination revealed a complete left facial paralysis. (Figs. 6A, 7A and 8A.) The left pupil was dilated and fixed, and a massive white area was present in the lower outer quarter of the retina. Below the bullet wound of the cheek, sensation was lost over an area approximately 3 inches in diameter, and there was some weakness in the muscles of mastication on the left. Hearing in the left ear was totally lost. No other signs of nerve injury were elicited. The right side of the face was normal.

For a period of four months, the patient wore a plastic hook in the corner of the mouth and attached around the left ear, to support the left side of the mouth. Repeated neurologic examinations revealed no evidence of regeneration of the facial nerve during this period. The paralysis was therefore regarded as permanent and the patient was transferred to the Plastic Surgery Department for treatment.

Under local anesthesia, a flap of the temporalis muscle, about ½ inch in diameter and 3 inches in length, was dissected from the head of the coronoid process through a vertical incision. The fascia of the muscle flap was reflected downward and split into two parts, one for each eyelid. Profiting by our experience in the previous case, wherein we had depended entirely upon the temporalis muscle flap, which reached only to the mid-portion of the eyelid and thus failed to support the lower lid sufficiently to permit full closure of the lids, the pedicle in the present case was made of proper length to reach the inner canthal region, in the hope of providing the necessary support. A tunnel was made beneath the skin over the malar bone and

across the upper and lower lids, the two halves of the pedicle were delivered through these tunnels and the distal ends were sutured into the inner canthal region.

Through an intra-oral incision along the anterior border of the masseter muscle, the anterior half of the muscle was pedunculated from its attachment at the lower border of the mandible. This pedicle was made at least one-third larger than that used in the first case in the belief that the results might thus be improved. The distal end of the pedicle was split and the flap was threaded through a tunnel constructed beneath the buccal muscosa to the corner of the mouth. The two ends were then passed through the body of the orbicularis oris, one through the lower lip, the other through the upper lip, and sutured to the muscle near the midline. To accentuate the nasolabial fold, the flap was sutured to the outer border of the orbicularis oris at its junction with the risorius muscle. A light pressure bandage was applied to the left half of the face.

To prevent swelling and intervention of the mucous membrane between the upper and lower teeth, a thin mold of dental wax was inserted between the teeth and soft tissue of the cheek and left in place for several days. The pressure bandage was removed at the end of one week.

The most noticeable disfigurement at this time was the paralysis of the left half of the forehead and eyebrow region. To correct this condition, a flap of the right frontalis muscle, ½ inch wide, was detached from its insertion, swung across to the paralyzed side, and fixed to the body of the obicularis occuli supercilia muscle and the lower portion of the paralyzed frontalis muscle.

Although the patient had support of the lower lid immediately following operation and the lids remained closed when he slept, he was cautioned against exerting the muscles of mastication for two weeks. After this period, he was instructed to begin reeducation of these muscles by clinching his teeth. By the end of the third week, he could partially close the lids on tightly clinching the teeth. The function of the lids continued to improve, and after the fifth week he was able to close the eyelids at will.

The patient had no controlled contracture about the corner of the mouth for a period of four weeks. In order to re-educate the muscle, he practiced at length before a mirror, and from the third week postoperatively, received daily electrical stimulation of the muscle. The first motion about the corner of the mouth was observed at the end of the fourth week. Strangely, he could move the corner of the mouth only by clinching his teeth and moving his right ear at the same time. One week later, he was able to contract the corner of the mouth without moving his ear, and thereafter contracture of this area progressively improved.

Nine weeks elapsed before any motion was apparent in the eyebrow region, and then only a slight twitching of the inner half of the left brow obliquely upward and medially was present. Four weeks later, the right eyebrow became extremely arched, producing a marked contrast in the two halves of the forehead. With a No. 11 Bard Parker knife blade, a small incision was made in the skin of the forehead ½ inch above the middle third of the right eyebrow, the greater portion of the frontalis muscle was incised horizontally down to the periosteum and a pressure bandage was applied. This decreased to some extent the overcontracture of the frontalis muscle. The contracture of the frontalis pedicle on the left was not pronounced at the patient's last observation, six months following operation, though the eyebrows were symmetrical when at rest and motion was still improving.

After the fourth month, motion of the eyelids and about the corner of the mouth improved only slightly. At six months, the patient could close the eyelids and contract the corner of the mouth only by clinching the teeth. (Figs. 6B, 7B and 8B.) With his mouth open, he could retract the left side of his face on holding the muscles of mastication tense.

Electrical stimulation to the facial nerve had no apparent effect until seven months following operation. At that time, a little movement of the muscles of expression of the lower half of the face, indicating a slight regeneration of the nerve to this group of muscles, was observed on stimulation of the nerve just anterior to the mastoid process. Whether regeneration of the nerve will continue is difficult to predict. In any event, correction of the paralysis was satisfactory by the end of the second month following operation.

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DISCUSSION

Donald M. Glover (Cleveland, Ohio): I can only express admiration for this beautiful contribution to repair of the very disfiguring effects of facial paralysis. I cannot discuss it because I have not done the operation in this way. Frankly, I have always been a bit skeptical about the future of muscle slip transplants from limited experimental observation, but the results shown are convincing and the method deserves wider use than it has had.

I would like to ask a couple of questions of the essayist, if I may: First, about the future of muscle slips, whether or not he has had any opportunity to observe them over long periods of time to determine how much fibrosis takes place in the muscle slip and how much function remains permanently? In this particular case, with the beautiful result which is unquestioned, I thought that at the outset the patient had a little facial muscle function before the operation and I was wondering if that was a complete nerve loss or if there was any function at all in the nerve or any tendency to regenerate on the part of the facial nerve.

It has been observed, I think, by almost everyone who has done the fascial transplant operation for fascial paralysis over a period of years, that the patients so treated, develop apparent movement of a slight degree in the side which is paralyzed. This movement appears to be contributed by the tension on the unaffected muscles of the good side. These patients may thus have a little sham movement on the paralyzed side which gives the impression of function which is not actually there.

Edward A. Kitlowski (Baltimore, Md.): This work by Dr. Adams again brings up a question which has puzzled us through the years: What function remains after a period of years in slips of muscle and how much fibrosis takes place?

As Dr. Glover mentioned, we have evaluated paralysis in many cases in this way: In a great many of the cases there is some regeneration of the nerve. Now, the flaccidity of the face stays because the muscles on the good side have overstretched the muscles on the weakened side, so that even though some nerve supply comes back, that muscle is overstretched so that it cannot function in opposition directly to the muscles on the other side.

With simple fascia transplants, you can help that muscle to such an extent that I will even go further than Dr. Glover and say that in some of these cases, we believed definitely that there was muscle function after a period of years. That muscle has had a chance to contract some, and will then exhibit its activity in conjunction with that contraction.

In cases of Bell's palsy, we have always thought it very important that early, very early, a hook attached to a head strap be put in the corner of the mouth to keep traction on the affected side. Quite frequently, if that is done conscientiously, the muscle will not be damaged during the period when that nerve is coming back and what looks like a very sad result will ultimately show a very satisfactory face.

I managed to get some of the statistics from Dr. Lexer's clinic, where they had done sixteen of these muscle transplants of the face. After experience with sixteen of them over a period of about six or eight years, Dr. Lexer decided that they were not worth the doing. Apparently there was so much fibrosis that it simply acted as straps, and fascia transplants would be just about as satisfactory.

We believe, as in some of Dr. Owens' work, that where a fascia strip is fastened to the masseter and is permitted to take on some of the function of contracting, you can get some permanent muscular effect, because you have not traumatized the masseter muscle.

As mentioned before, I do not have enough experience with these muscle transplants to say how long they will survive as such. I believe that a slip of muscle handled in this way, particularly where it is split down, as Dr. Adams explained, will unquestionably not survive and atrophy may be a slow process over a period of two or three years or even longer; but I still believe that in the end, he will again have the same thing as one gets with a strip of fascia.

Neal Owens (New Orleans, La.): No method for the correction of facial paralysis offering completely satisfactory support and animation has been developed. The improvement reflected from the use of muscle transplants or fascial transplants incorporated in functioning muscle has been sufficient to be of great comfort to patients with complete facial paralysis. Effort directed toward the development of a surgical procedure which will improve existing methods is worthwhile, if it does little more than to stimulate renewed interest.

Correction of facial paralysis, should entail more than actual support of sagging muscles, because support without reanimation means little comfort to the patient.

In answering some of the questions regarding the fibrosis of muscle slips, I can say that I have observed one case repaired by muscle transplants for about twelve years. One of the first cases recorded was corrected over twelve years ago and that case was corrected by means of muscle slips from the masseter muscle. Three slips were utilized, bringing one to the upper lip, one to the angle of the mouth and one to the lower lip. A satisfactory result has persisted through a period of over eleven years. This patient has been examined regularly from year to year. I have seen him within the past three months and the result is better today than it was two months following the operation.

It has been found, on the basis of experience, that these cases will show definite improvement during one, two or three years. I do not mean to imply that this is a reflection of more power from the muscle but probably is a combination of increased muscle power plus a degree of animation resulting from increased coordination, which is developed as a result of exercises done before a mirror. This is a most important procedure to have patients follow. Unless the patient has the necessary desire to develop animation, which can be attained only through constant exercise and practice,

the result will be proportionately less. Patients are instructed routinely regarding the exercise of the masseter muscle. By comparing movements which they visualize in a mirror, they learn to develop a marked degree of reanimation.

During a twelve-year period, twelve cases have been corrected. Three or four of those were done by muscle slip transplants, the others were done by fascia transplants, incorporated in the masseter muscle. I was of the opinion that the fascia transplant subjected the masseter muscle to less truma and for that reason discarded the muscle transplant operation for that one utilizing the transplantation of fascial strips into the masseter. There are three things which one should consider if planning to use a muscle transplant operation: (1) possible injury of the nerve and muscle; (2) the inability of advancing muscle transplants past the midline of the lip and (3) disturbing or applying too much tension on Stensen's duct.

Patients corrected by means of fascial transplants incorporated in the masseter muscle have been just as satisfactory, in so far as I can evaluate, as those corrected by utilization of muscle transplants. The use of fascial transplants makes a much simpler operation and one that can be approached by the extra-oral route, avoiding the possibility of infection.

Paul W. Greeley (Chicago, Ill.): There is one point which I do not believe has been stressed adequately, and one which has always been difficult for me to decide, that is, just what patients should be selected for operation. I have not been able to find any test, either myself or from information given to me by others that will answer this question accurately.

The surprising thing is that many patients who have been operated upon by simple support of fascial strips very soon thereafter appear to have some motion on that side of the face. I have come to believe that many of these individuals have already had a certain amount of spontaneous regeneration of nerve function, which has never been perceptable or complete. Hence, when fascia strips have been inserted in the paralyzed side of the face so as to offset the overpull of the normal side, it is then possible to note a certain amount of motion in the muscles on the affected side, even though it may be slight.

Consequently, I have come, as time has gone on, to operate on more and more individuals with facial paralysis much earlier than I had in the past. I believe if an individual has gone arbitrarily, say, from three to six months, and has not shown definite signs of a very marked and dramatic return of the function of the muscles from the nerve injury on that side, that one is justified in recommending some type of fascia support operation. This will miminize considerable permanent atrophy from disuse, and at the same time will encourage the patient to utilize what motion remains. I do wish to make it clear, however, that I am speaking of the patient who has a partial return of his nerve function, and not of the individual with a known, permanent, complete paralysis as described by Dr. Adams.

Wm. Milton Adams (closing): Thank you, Dr. Glover, Dr. Kitlowski, Dr. Owens and Dr. Greeley.

In regard to the question of complete facial nerve paralysis in the cases presented, it was the opinion of Captain Bill Livingston, of the Peripheral Nerve Surgical Department of the U. S. Naval Hospital at Oakland, that the paralysis was complete in both cases and the condition could be improved only by facial suspension or muscle transplantation.

As to the future function of the muscle transplant, my experience has been that it continues to improve. Whether the transplant will or will not function depends upon the nerve supply. Once the nerve supply is destroyed, the muscle atrophies. This has been conclusively proved by army and navy surgeons who have been using muscle substitution in the extremities, particularly the hand. Whether the effect of the operation will be lasting or fibrosis will develop two or three years later likewise depends entirely upon whether or not the nerve supply to the transplanted muscle has been interrupted.

Dr. Owens has pointed out the necessity for daily exercise of the transplant. Without supervised reeducation of the muscles, preferably before a mirror, one cannot expect maximum function. We believe that the use of three muscles gives the patient the best prospect of restoration of function, with a more normal direction of pull. Granted that the nerve supply is ample, the end result will depend upon the patient's persistence in carrying out the prescribed exercises.

* All the illustrations in this article are published through the courtesy of The Williams & Wilkins Company who published them originally in their journal, Adams, William Milton. The use of the masseter, temporalis, and frontalis muscles in the correction of facial paralysis. *Plastic & Reconstr. Surg.*, 1:2, September, 1946.

SURGICAL MANAGEMENT OF EXTENSIVE AVULSIONS OF SKIN*

CARLETON MATHEWSON, JR., M.D. AND ALEX GERBER, M.D.
San Francisco, California

EXTENSIVE avulsions of skin and subcutaneous tissues are not uncommon injuries encountered in association with automobile and wringer accidents. Frequently such lesions become complicated surgical problems demanding extensive plastic procedures and long periods of hospitalization because of improper early management. Although seldom dangerous to life, these wounds are all potentially infected and, unless treated as acute surgical emergencies, inevitably lead to serious complications.

In May, 1939, Alfred W. Farmer of Toronto, Canada, presented before the American Surgical Association four cases of severe avulsion of skin treated by immediate complete excision of all of the avulsed skin, débridement of the traumatized area, removal of all of the subcutaneous fat from the avulsed skin and its replacement as a full thickness skin graft on the denuded area. His results were excellent but it was evident from the discussion of his paper that many considered the method too radical for general adoption.

Our experience with Dr. Farmer's method has been excellent whereas out experience with similar injuries treated by other methods has been most discouraging. Although not infrequently the avulsed skin and subcutaneous tissues appeared not badly damaged and often remained attached to a rather large pedicle, careful débridement of the wound and accurate replacement of the avulsed skin was often followed by engorgement of the skin flaps and gangrene. Occasionally, the skin would remain intact but the attached subcutaneous fat would become necrotic and cause secondary necrosis and slough in the grafted area. Fibrosis and contracture of the subcutaneous tissues were frequent complications. These and other observations associated with the treatment of this disabling injury are recorded in the following case histories and discussion:

CASE 1. Mrs. A. A., a thirty-seven year old housewife, entered San Francisco Hospital in April, 1938, following an automobile accident. There was a deep laceration of the palm of the right hand and fractures of the distal end of the right radius, the base of the fourth metacarpal, the navicular and pisiform bones. The skin, subcutaneous tissue and palmar fascia were stripped free of their attachments and avulsed to the base of the metacarpal bones of the fingers. (Fig. 1A.) The flexor tendons, although intact, were stripped free of the surrounding tissues so that they could be lifted away from the volar surface of the hand. The superficial and deep palmar arches were intact. The entire surface was ground full of grease and dirt. The wound was carefully débrided by sharp dissection and by repeatedly submerging the hand in saline solution until all devitalized tissue and contaminants had been removed. The contused skin edges were removed by sharp dissection. After careful hemostasis the wound was closed with interrupted silk sutures. Because of the precarious blood supply to the fingers and thumb, no attempt was made to reduce the fracture of the radius. A pressure dressing was applied and the extremity immobilized in a plaster body spica, extending from the tips of the fingers to the waist with the arm held at 90 degrees flexion at the elbow and 90 degrees abduction at the shoulder. The postoperative course was uneventful. The hand was dressed on the twelfth postoperative day at which time the wound in the palm of the hand was healed. An attempt was made to reduce the fractures but proved unsuccessful because traction caused undue interference with the circulation. This patient was started on early active physiotherapy but, regardless of the fact that the skin remained intact, the subcutaneous tissue became fibrotic and caused considerable flexion contracture of the wrist. Subsequent excision and regrafting of this area produced the final result seen in Figure 1B.

Comment. This patient, treated before Dr. Farmer's contribution, demonstrates the advisability of immediate extensive and careful débridement of such wounds to prevent infection. Very careful immobilization is important

* From Stanford University and the University of California Surgical Services, San Francisco Hospital, San Francisco, Calif.

FIG. 1. A, Case I. avulsion of skin and subcutaneous tissue from palm of hand.

for the same reason. Regardless, however, of the primary wound healing and absence of infection, secondary fibrosis of the subcutaneous fat and areolar tissue in this patient led to contracture necessitating subsequent excision and grafting.

CASE II. Mrs. M. R., a thirty-two year old widow, entered Santa Clara County Hospital in September, 1941, following an automobile accident. There was a compound fracture of the right tibia in the lower third and an extensive avulsion of the skin of the anterior, posterior and lateral surfaces of the lower leg extending from a point just below the knee joint to the ankle joint. There was also an avulsion of the skin of the lateral surface of the right thigh. The avulsed skin was attached along the medial surface of the leg throughout the length of the avulsion. The patient was taken to surgery immediately. After extensive and careful débridement of the entire wound the fracture of the tibia was reduced and held by the application of a metal plate. The avulsed skin and subcutaneous tissues were carefully replaced and sutured. Pressure dressings were applied and the leg was placed in traction. Fourteen days later, this patient was transferred to the San Francisco Hospital where it was noted that the entire avulsed skin had become necrotic. It was necessary to remove almost all of the skin of the right lower leg and a portion from the right thigh. (Fig. 2.)

Comment. This patient demonstrates the usual fate of replaced skin and subcutaneous tissue. As might be expected, she became a difficult nursing problem and recovered the use of the right lower extremity only after months of hospitalization and extensive skin grafting.

CASE III. C. G., a three and one-half year old male child entered San Francisco Hospital in November, 1941, following a street car injury. The

FIG. 1. B, final result after replacement of avulsed flap and secondary excision of scar tissue.

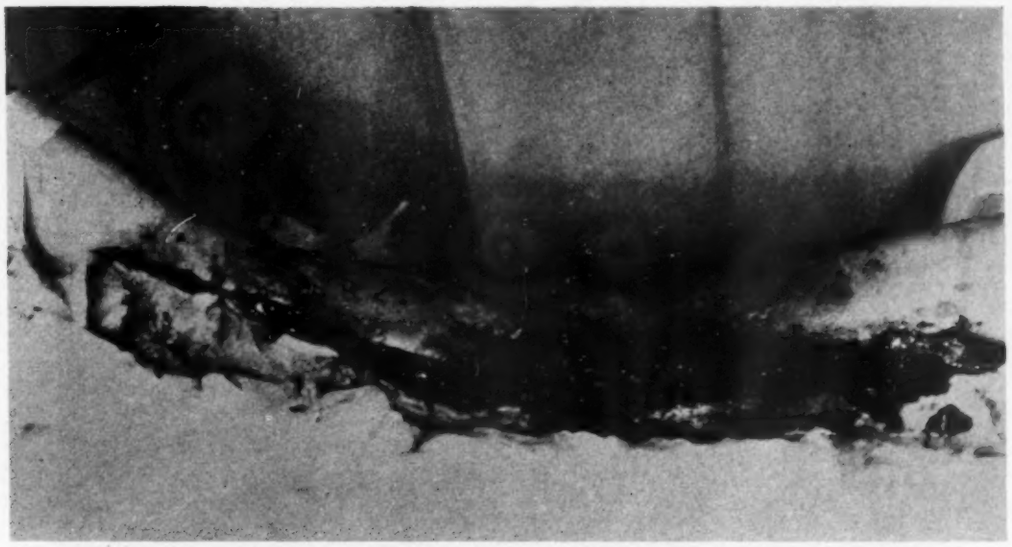


Fig. 2. Case II. Complete necrosis of avulsed skin and subcutaneous tissue two weeks after replacement without removal of subcutaneous fat.

roller on the catcher on the front of the street car had avulsed the skin and subcutaneous tissue of the entire left ankle and foot, including disarticulations and avulsion of all but the great toe at the metatarsophalangeal joints. There was only a small portion of skin still attached near the ankle joint. Figure 3A through Figure 4B demonstrate the operative procedure undertaken. After the remaining portion of attached skin was removed, the entire skin flap was stretched on a board and the subcutaneous fat removed by sharp dissection. The exposed denuded bone of the toes was removed with rongeurs. The denuded foot was carefully débrided by sharp dissection and irrigated with saline. The full thickness skin graft was carefully sewn back in place. A missing area of skin was replaced with a three-fourth thickness split graft from the right thigh. A paraffin dressing was placed over the grafted area. Moist gauze and sea sponges were applied as pressure dressings. A long leg cast completed the dressing. In order to preserve the great toe this single area was grafted with the avulsed skin leaving the subcutaneous fat in place. Figure 5 shows the foot healed. The initial dressings were not disturbed for two weeks. There was practically a complete take of this graft with the one exception of the great toe where the subcutaneous tissue was left intact. This area became gangrenous, was removed and regrafted.

Comment. The excellent result obtained in this patient is an admirable demonstration of the method proposed by Dr. Farmer for the treatment of extensive avulsion of skin and subcutaneous tissue. Had we not inadvisedly left subcutaneous tissue on the skin flap covering the great toe, in all probability there would have been a complete take of this entire graft.

Case IV. Mrs. E. G., a fifty-nine year old housewife, was admitted to the San Francisco Hospital in January, 1942, following a wringer injury. Apparently, the wringer had run over the hand and forearm, avulsing completely the skin and subcutaneous tissue of the forearm from the cubital fossa to the wrist joint except for an attachment of the skin posteriorly along the interosseous ridge. The sensations and circulation of the hand remained intact. After careful cleansing with soap and water, ether and alcohol, the laceration about the cubital fossa was carefully débrided by sharp dissection. The loose skin cuff covering the arm was then incised longitudinally on the volar surface of the forearm, forming two equal-sized skin flaps attached on the posterior surface of the arm. The subcutaneous tissues were then meticulously removed from the undersurface of both skin flaps, leaving only full thickness skin flaps. (Fig. 6A.) The remaining portion of subcutaneous tissue was removed by sharp dissection from the fascia overlying the musculature of the forearm. After careful hemostasis, the wound was irrigated with normal saline and the full thickness skin flaps were sutured in place with interrupted silk sutures. Paraffin gauze was applied to the wound with cotton batting and sea sponges held with an ace elastic bandage superimposed as a pressure dressing. The extremity was placed in a plaster cast for immobilization. The wound was dressed on the seventh postoperative day at which time it appeared that about 95 per cent of the grafts had taken. It was noted, however, that the flaps seemed blue and congested and there was a

FIG. 3. A, Case III. appearance of foot immediately following injury; B, avulsed skin prepared as full-thickness grafts by removing all subcutaneous fat.

small area of necrosis on the volar surface of the forearm where the two flaps had been sutured together. (Fig. 6B.) This area of necrosis increased in size during the following weeks and did not heal completely for about four months. (Fig. 6C.)

Comment. This patient raises the question of the advisability of preserving the marginal attachments of extensively avulsed areas of skin. One is reluctant indeed to separate attached margins of skin for fear of destroying the small amount of blood supply remaining. However, this patient and others have led us to believe that regardless of pressure dressings these attached flaps are apt to become congested with arterial blood and, because of inadequate venous drainage, are subject to chronic passive congestion which is detrimental to their preservation. In our experience, attaches flaps denuded of subcutaneous tissue do not do as well as free full-thickness grafts.

CASE V. Mr. L. B., a fifty-two year old steel worker was admitted to the San Francisco Hospital in May, 1942, following an automobile accident. There was an extensive laceration of the palm of the right hand with an avulsion of skin approximately about two-thirds of the area of the palm.

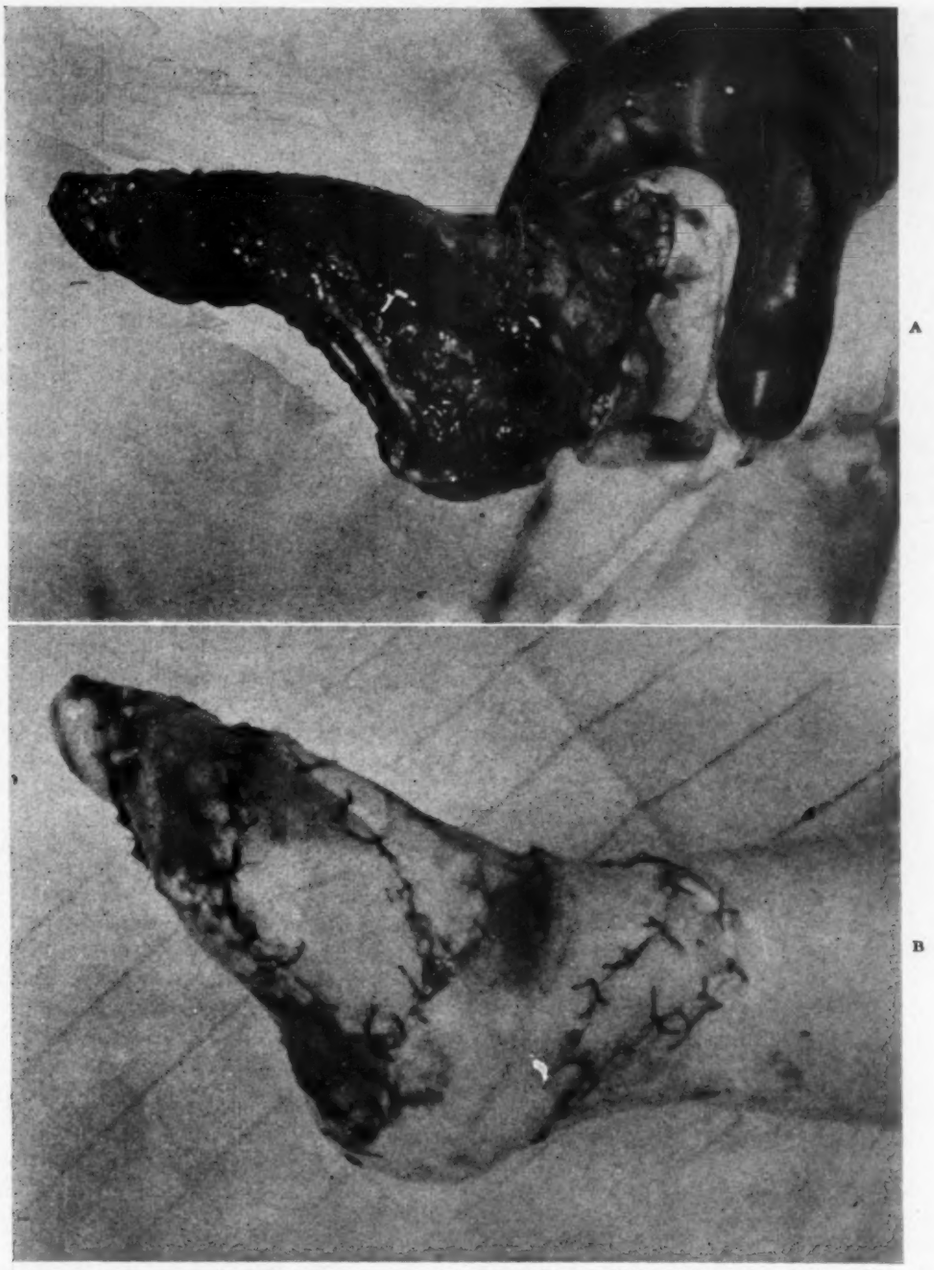


FIG. 4. A, Case III. denuded foot prepared for grafting; B, full-thickness grafts in place.

No tendons or nerves were severed. The right hand was meticulously scrubbed with soap and water and cleansed with ether and alcohol. The skin flap was incised at its base and removed. All of the subcutaneous tissue was removed from the excised skin by sharp dissection. The palmar surface of the hand was débrided carefully and irrigated with saline. After hemostasis, the avulsed skin was replaced as a free full thickness graft. A paraffin dressing covered with sea sponges and an ace elastic bandage was applied. The hand and upper extremity were encased in a plaster cast. The wound was dressed on the tenth postoperative day at which time it was noted that there was a complete take of the graft. Figures 7A and 7B demonstrate the hand before and after treatment.

Comment. This patient had a similar injury, although not complicated by underlying fractures, to the first patient reported. Here the avulsed skin was completely removed and replaced as a free graft. In the first patient, the avulsed tissues after débridement were replaced

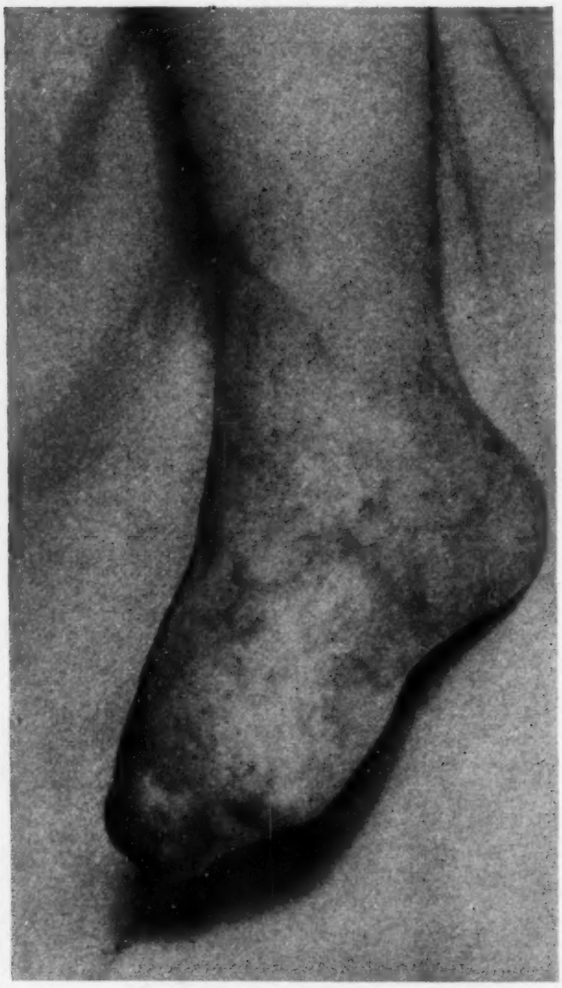


Fig. 5. Case III. Final result.

intact. Although the two injuries are not completely comparable, the area of avulsion of skin was the same and the result in this patient far superior to the first.

Case VI. F. J., a two and one-half year old colored boy, entered San Francisco Hospital 7:20 P.M. December 3, 1946. He had been run over by a truck thirty minutes previous to entry. The truck had run over the left lower extremity. There was an avulsive injury of the lower one-half of the left leg and foot, the entire thickness of the skin and subcutaneous tissue being lifted off the fascia, extensor and flexor tendons, leaving the largest flap of skin attached only at the base of the toes on the volar surface of the foot. There was a moderate amount of bleeding. The entire area was ground full of grease and dirt. The entire left lower extremity was cleansed thoroughly with soap, water, alcohol and ether and the large flaps were cut free from the extremity and given to an assistant who thoroughly scrubbed the flaps with soap and water and removed every bit of subcutaneous tissue from the underside of the skin, leaving the full thickness skin for a graft. The wound itself was thoroughly washed with soap and water, and irrigated with saline so that every particle of dirt possible was removed. All the contused and necrotic tissues were cut away. Bleeding was controlled by pressure. The extremity was then redraped, the operating team changed gowns and gloves and a new set of instruments used for the actual surgery. Numerous thrombosed vessels were encountered. These were all débrided away as well as the contused muscle and subcutaneous tissue. The anterior tibial artery appeared to be pulsating as well as the dorsalis pedis artery. The posterior tibial artery was intact, the tendons were inspected and the only tendon which had been avulsed was the long flexor of the large toe. This tendon was approximated with No. 60 cotton. The skin which had previously had all of the subcutaneous tissue removed was then fitted in place on the foot, covering the entire defect with the full thickness skin graft. The margins of the graft were sutured with interrupted No. 60 cotton sutures. A pressure dressing was applied. On December 12th, the pressure dressings were removed and approximately 60 per cent of the graft had taken. The areas which had not taken were those areas of skin which at the original examination appeared to have been extensively burned by friction. On January 6, 1947, the granulating areas of the wound were covered with split thickness grafts. Figures 8A and 8B demonstrate the wound before and after grafting.

Comment. This patient is another who was treated by the method of Farmer. Although approximately 40 per cent of the original graft was lost, the method of treatment was not at fault. It was anticipated that about that amount of the orginal skin was badly burned and might not survive. That skin should have been discarded and replaced with three-fourth thickness free grafts at the original operation.

Case VII. Mr. E. V., a sixty year old white engineer, entered San Francisco Hospital in May, 1947, following a truck accident. The truck had knocked him down and the rubber tire on one rear wheel had rubbed against and squeezed the tissues of the left thigh and left lower abdominal wall. Examination revealed an extensive laceration in the left groin with an extensive avulsion of all of the skin and subcutaneous tissue of the entire left thigh and left lower abdominal wall. The patient was taken to surgery where after careful preparation of the entire left thigh and abdominal wall, the margins of the laceration in the left groin were carefully débrided by sharp dissection. It was

noted that all of the skin of the left thigh, left lateral buttock and left lower abdominal wall had been completely avulsed from the underlying tissue except along a margin about 4 cm. wide extending from the left groin to the medial side of the left knee. An incision was made from the anterior superior spine of the left ilium to the outer margin of the left knee joint. This incision joined the laceration in the left groin, thus forming three very large skin flaps. One skin flap was turned upward over the abdominal wall and the two on the thigh were reflected medially and laterally to their attachment on the medial side of the left thigh. With the flaps reflected the entire left thigh from the groin to the knee and the entire lower left abdominal wall were completely denuded of skin and subcutaneous tissue. All of the subcutaneous fat was dissected free from these skin flaps by sharp dissection and the underlying wound carefully cleansed by irrigation and removal of all devitalized tissue. The full-thickness skin grafts still attached at one margin were replaced on the region from which they had been removed and sutured in place with quilting sutures of fine silk tied over small pieces of gauze. The grafts were sutured together with interrupted silk sutures and the entire area "pie crusted" with small incisions for drainage. An extensive pressure dressing was applied. The postoperative course was uneventful until the fifth day when the patient developed an extensive ileus, became extremely excited and violent and died in delirium tremens. Examination of the grafted area after death revealed that the full thickness skin grafts all appeared viable and were adherent to the underlying tissues with a thin fibrinous exudate. There was no evidence of infection and it seemed probable that these grafts would have taken had the patient lived.

Comment. This patient had the most extensive avulsion of skin that we have encountered. He was treated according to the method of Farmer except that the attached margins of the skin flaps were left attached. The patient's unfortunate death on the fifth day deprived us of the end result of such an extensive primary graft; however, there was every evidence at the time of death that the grafts were attached and living and in all probability would have survived.

COMMENT

It may be seen from the case histories reported that our best results have been obtained in those cases in which we have had the courage to remove all of the subcutaneous fat from the avulsed skin and to replace the skin as full thickness grafts. In the discussion of Dr. Farmer's original paper, Dr. Sumner L. Koch, of Chicago, questioned the advisability of detaching flaps which were attached by a wide margin. Dr. Farmer was opposed to leaving attached margins and stated that the only skin that he had lost was in a case in which the skin flaps were not detached. Dr. John Homans, of Boston, mentioned the possibility of chronic passive congestion developing in attached flaps because of retained arterial blood supply and insufficient venous drainage. In our experience the important factor in this connection is the removal of all subcutaneous fat from the avulsed skin. This can be accomplished most simply by completely removing the skin and having it prepared by an assistant while the wound is being prepared for grafting. Such a procedure will certainly shorten what is often a long and tedious procedure. Furthermore, it seems highly improbable that skin which has been denuded of all its subcutaneous tissue will receive sufficient arterial blood from the attached margins to alter its fate one way or another. We have found it convenient at times to leave the margins attached and as may be seen in Cases IV and VII such flaps do survive. No doubt, those in favor of leaving the attached margins have in mind similar situations produced surgically, such as the skin flaps raised in radical amputations of the breast and in removing the subcutaneous tissues in elephantiasis of the legs. It should be remembered that these flaps are produced surgically with a minimum of trauma, whereas avulsions due to trauma presuppose more or less extensive injury to both the skin and underlying tissue. Two patients in our series (Cases I and IV), in which the skin flaps remained attached, did develop what appeared to be chronic passive congestion of the attached skin. Both flaps survived. However, they might have done better had they been completely detached. The results obtained following complete detachment of the skin have been best and seem to justify the procedure.

There can be little doubt of the advisability of removing subcutaneous fat from the avulsed skin. Regardless of the appearance of this tissue it is usually severely traumatized as is evidenced by the extensive thromboses of vessels encountered in its removal. Although occasionally replaced flaps of skin and subcutaneous fat will survive initially, subsequent fibrosis of the

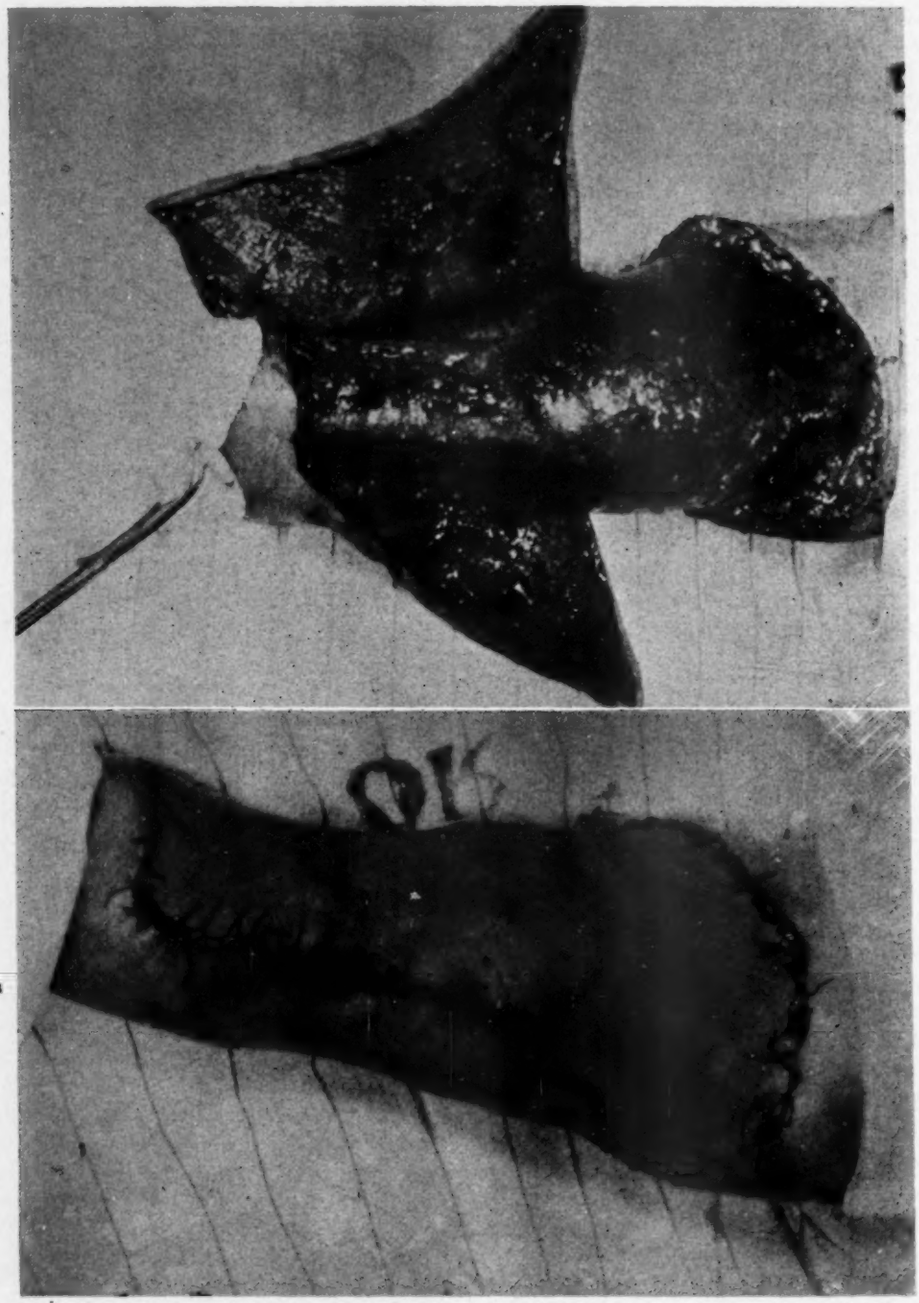


FIG. 6. Case IV. A, skin flaps denuded of subcutaneous fat; B, skin flaps ten days after suture.

subcutaneous tissue is apt to lead to troublesome contracture with deformity and often results in persistent peripheral chronic edema. Here again one is faced with a difficult decision at the original operation. Excision of extensive areas of subcutaneous fat appears at the time to be an unduly radical undertaking. However, experience has shown the wisdom of such a procedure. Secondary gangrene and infection of large areas of avulsed tissue as demonstrated in Case II is not only dangerous to the life of the patient but the treatment involves long periods of hospitalization and requires extensive surgical procedures for its correction. Case III demonstrates the inadvisability of leaving subcutaneous fat attached particularly to unattached skin. In the treatment of this extensive avulsion injury the only skin lost was that small

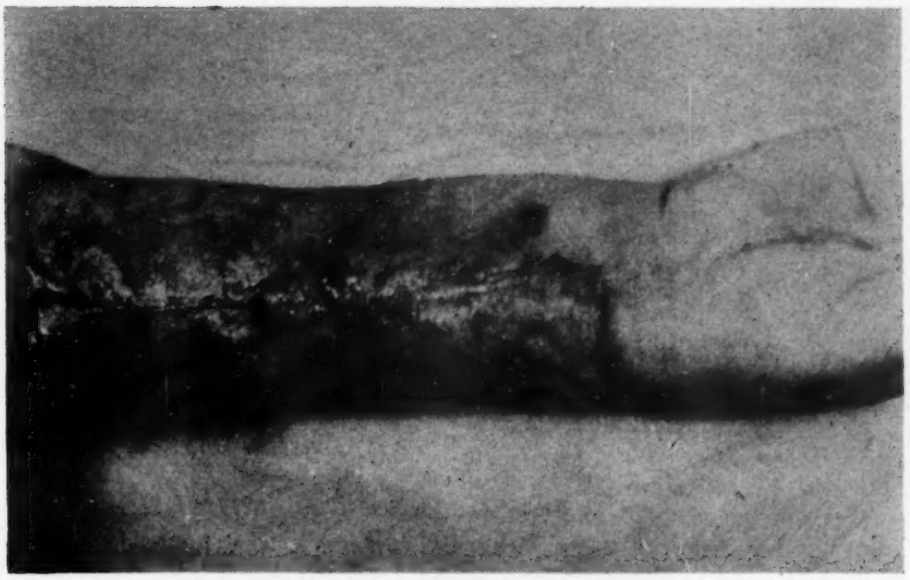
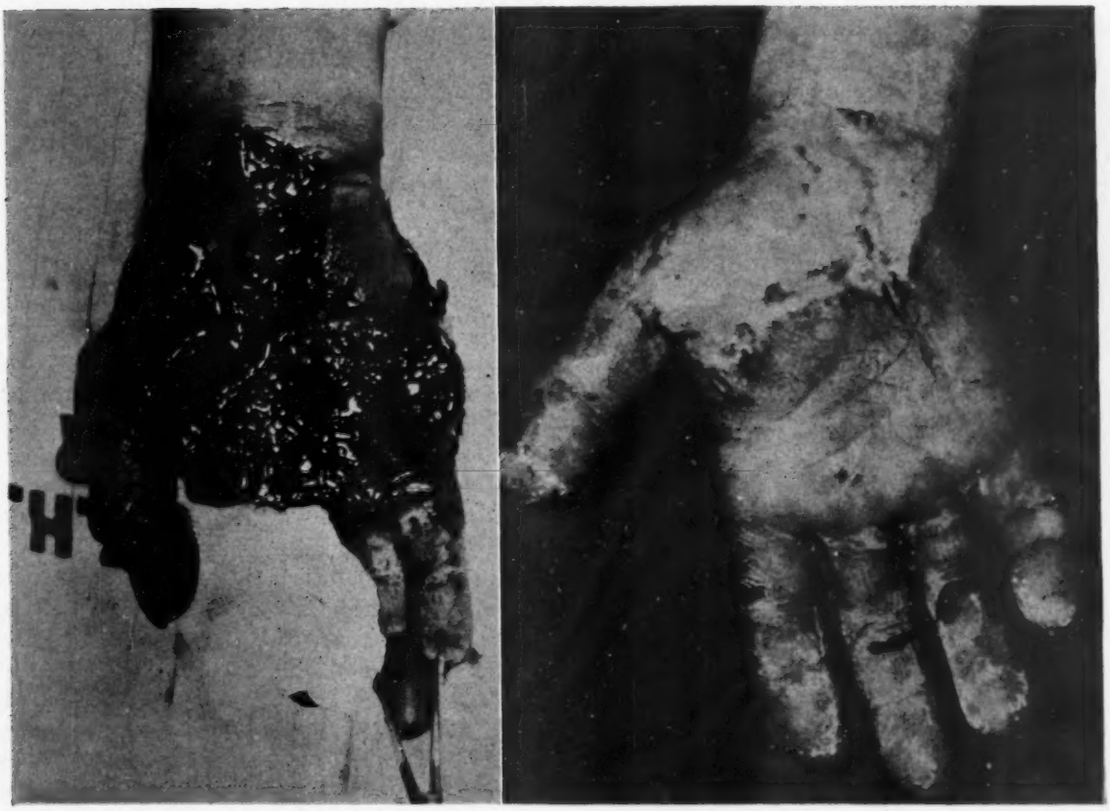


Fig. 6. C, result after four weeks.



A B

Fig. 7. Case V. A, avulsed skin reflected from palm; B, appearance of hand two weeks after replacement of avulsed skin as a free, full-thickness graft.

FIG. 8. Case VI. A, foot and leg prepared for grafting.

area over the great toe where fat remained attached to the grafted skin.

As was emphasized in Farmer's original

FIG. 8. B, final result.

article, the skin when removed and prepared for grafting need not be handled too carefully but care must be taken that all of the subcutaneous fat is removed. This can be accomplished readily by pinning the inverted skin on sterile boards (Fig. 3B) and cutting the fat away with a sharp knife. If the skin has been badly contaminated at the time of injury, it should be cleansed thoroughly by scrubbing with soap and water before it is replaced. Those areas of skin which obviously have been too badly damaged by the original trauma to survive should be cut away from the full thickness graft and discarded. This skin can be replaced at the original operation with three-quarter thickness grafts taken with a dermatome. This is an extremely important step in the procedure inasmuch as necrosis of devitalized areas of skin in the grafted area may lead to infection and jeopardy of the living graft. Case VI demonstrates the fate of devitalized skin replaced as a graft.

Care should be taken that the grafted skin is not overstretched. Overstretched skin will retract, leading to areas of granulation tissue at the margins which will cause the formation of scar tissue and contracture. In placing the grafts, if multiple, one should avoid placing the margins across flexion creases such as the ankle or wrist joint. Skin stretched over bony protuberance such as the os calcis may lead to necrosis if tension is too great. Large grafts in our experience should be perforated at intervals for drainage and should be securely held in place with quilting sutures. Pressure dressings

should remain in place from ten to fourteen days unless evidence of infection develops.

The preparation of the area to be grafted is of equal importance to the type of graft placed upon it. Very meticulous cleansing and removal of all devitalized tissue and absolute hemostasis are essential to primary healing. Unless these patients are treated as acute surgical emergencies, infection in the wound will preclude the possibility of primary grafting. Immobilization in plaster insures proper rest of the injured part during the healing period.

SUMMARY

Seven patients with extensive avulsions of skin and subcutaneous tissue are reported with the details of treatment and comments on the final results. In our experience the method of treatment proposed by Dr. Farmer of Toronto, Canada, in 1939, has given the best results. His treatment involved the complete removal of all avulsed skin, careful débridement of the remaining denuded areas, removal of all subcutaneous fat from the skin and its replacement as a full thickness graft to the area from which it was removed. The importance of treating this type of injury as an acute surgical emergency is emphasized.

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DISCUSSION

Harry B. Macey (Temple, Texas): Dr. Matthewson's paper interests me a great deal, because for several years we have been using a similar procedure in the treatment of chronic lymphedema involving the lower extremities. Even though this latter condition is not traumatic in origin, treatment is along the same line as presented in this paper. By excising the skin, lymphedematous tissue and fascia and applying a thick split skin graft, we have accomplished the same results that was accomplished here. Some of our patients have had a tendency to show some stasis changes in the thick splits especially about the ankle.

The operative procedure we have employed has covered the entire lower extremity from the ankle to the knee. I would like to ask a question: Are there stasis changes, such as thickening and fibrosis in these full thickness grafts that have been reapplied?

Alfred W. Farmer (Toronto, Canada): I enjoyed Dr. Matthewson's presentation very much indeed. I have noted in our own center that despite the fact that this has been published and used for a long time, certain men who are very conversant with ordinary surgical procedures will not use this one. Why that is, I do not know.

A very well trained surgeon in our own hospital, less than a week ago, asked me to see a hand some days after an injury in which the large portion of the palm had been avulsed. He had sutured it back, leaving the avulsed skin attached at one side. There was a loss of coverage and that is in my own hospital.

The skin does not have to have any wound in it whatsoever to be avulsed. Workmen who have had their forearms pass through rollers will avulse all the skin and subcutaneous fat completely from the forearm or arm, without any wound in it whatsoever, simply by rolling the skin and subcutaneous fat off the deep fascia. A great number of such cases need no such procedure as this at all but some do. One has to judge from the appearance when the wound is seen whether the flap will survive or whether it will not.

Taking the flap off is a formidable procedure. However, nothing can be lost by so doing. You just take it off and take the fat off and put it back on. But those who are not used to doing this find the whole procedure a mental hazard.

Dr. Matthewson mentioned that Dr. Koch questioned the advisability of the procedure. Since that time, Dr. Koch has seen practically all of the cases that were mentioned in that original article and I think he changed his mind. We had them in when he came to pay us a visit.

The procedure has been used not only in patients with injury to the skin alone, but also in lesions in which there have been compound fractures of bone, associated with crushing injuries to the limbs. The bone lesion was handled at the same time with the whole skin being taken off a leg and put back on again. If, as Dr. Matthewson has said, the skin is very badly injured, it is necessary to discard it and use a split skin graft with a section of the skin which you have avulsed.

Dr. Matthewson's presentation was very interesting indeed.

Carleton Matthewson, Jr. (closing): I would like to thank Dr. Macey and Dr. Farmer for their discussion. I had hoped that certain questions in connection with this type of injury might be answered in the discussion of the paper. How large

should the avulsion be before one considers complete removal and replacement as a free graft? I believe that the decision does not depend upon the size but rather upon the blood supply of the avulsed tissue. If the margins of the avulsed skin, when still attached by a pedicle, bleed when traumatized, the blood supply is intact and the pedicle may be replaced. However, completely detached areas of skin should be treated as described before being replaced as a free full-thickness graft.

We have not seen chronic edema develop in these free grafts when all the subcutaneous tissue has been removed. As a matter of fact, chronic edema frequently has been successfully treated by removing the involved skin and subcutaneous tissue and covering the area with full or split thickness skin graft.

The question as to whether or not these flaps should be completely detached when still attached by a pedicle is answered, I believe, by the ease with which they can be handled when completely removed. If a margin is left attached, it becomes extremely difficult to remove the subcutaneous tissue from it. Unless the subcutaneous tissue is removed, a slough or contracture will occur. The blood supply obtained from an attached margin, I believe, is negligible. If you leave the margins attached, you will find in the process of removing the subcutaneous fat that it does not bleed and many of the vessels are thrombosed. As you approach the attached margin, you will find that the subcutaneous fat does bleed and there you may safely stop. The viability of the skin depends upon the blood supply to the subcutaneous fat.

INTRODUCTION TO MAJOR GENERAL HAWLEY'S SPEECH

FREDERIC W. BANCROFT, M.D.
New York, New York

I AM not going to let Major General Hawley, get up yet, because I have something to say about him.

Major General Hawley retired from the Army in June 1946 to become the first Chief Medical Director of the Veterans' Administration. He was first commissioned in the Army in 1916, and during an active service of almost thirty years, he was promoted through the successive grades from First Lieutenant to Major General.

I will not tell you when he was born but it was in West College Corner, Indiana. He received his A.B. degree from Indiana University, his M.D. degree from the University of Cincinnati, and the degree of Doctor of Public Health from Johns Hopkins University. During his Army career, he graduated from both the basic and the advanced course of the Army Medical School, from the Command and General Staff School and from the Army War College.

He has been an instructor in both the Army Medical School and the Medical Field Service School and was the Assistant Commandant of the latter school. Dr. Hawley served in France as a regimental surgeon during the first World War. Between world wars, he served in the Phillippine Islands and in Nicaragua, on the Nicaraguan canal survey of 1929 to 1931, as well as at various stations in the United States.

He was the first commanding officer of the Medical Replacement Training Center at Camp Lee, Virginia, which was opened in 1941. During the summer of 1941, before Pearl Harbor, he was sent to England as one of the special observers with the British. After the United States entered World War II General Hawley became the Chief Surgeon of the United States forces in the British Isles, and afterward Chief Surgeon of the European Theatre of Operations. As head of the Medical Service of the United States Army in Europe, he built or leased hospitals to the total of 203,000 fixed hospital beds. He supervised and directed the Medical Department in the theatre, which eventually reached the strength of 254,000 officers and men, including 16,000 physicians, 4,500 dentists and 18,000 nurses.

General Hawley was awarded the Distinguished Service Medal, Legion of Merit and the Bronze Star by the United States, the Legion of Honor and the grade of Officer, the Order of Public Health and the grade of Commander, and the Croix de Guerre with Palm by France, the Companion of the Bath and the Order of St. John of Jerusalem and grade of Knight by Great Britain, the Order of the Crown and the grade of Commander by Belgium, and the Presidential Medal of Merit by Nicaragua.

He is a Fellow of the American College of Physicians, a Fellow of the Royal College of Physicians of England, an Honorary Fellow of the Royal College of Surgeons of Edinburgh, and an Honorary Fellow of the Royal Society of Medicine of London.

Now, I had all this impressive official information about the man, but I felt that I would like to know something more about the individual, General Hawley, so I tried to find out from various sources. I called up Mather Cleveland because I knew that he had served under General Hawley in England. "Well," he said, "all I can tell you about General Hawley is that we were so damned thankful he was our chief over there that we couldn't say anything else. He was the squarest-shooter and the best administrator that I have ever known." Then he said, "Why don't you read Hawley's article in the last May number of S. G. & O? Don't you keep up with the modern literature?" I confessed, no, I had not read what General Hawley had written. Later that afternoon Dr. Cleveland called me again and asked if I had read the article. Then I looked at the May number. I wonder how many of you have read it, because I learned a good deal of the man, as Mather Cleveland had said I would. He has written something in which you would all be tremendously interested. The title of it is, "Did Cholera Defeat Custer?" From this article, I think you will learn a good deal of the interests of the man. Here is a doctor who has entered into the problem of epidemiology of cholera, of medical tactics, and Army tactics in the Custer campaign, but, above all, I came to the con-

clusion that he condemned dishonesty. God, how I would hate to have him as my enemy! I do not think he would be a very charitable enemy if you were crooked enough to get his dislike.

Then I tried to find out some more about General Hawley. I found that his father and his grandfather had practiced medicine, but I also found out that in addition to practicing medicine in Indiana, they had been interested in hogs, and I found out that General Hawley at present has a son who raises hogs, and General Hawley has an idea that when he gets out of this job, he is going back to Indiana and raise hogs, which, after all, is a good estimation of the man.

I also learned from other sources that when he first went to England, he had a habit of going down to the pubs along the waterfront, where he learned an authentic cockney accent, where he learned a good deal about the problems of the common man in England, and where his influence made the common man of England think a lot more of our commanding medical officer.

Now, my personal relationship in respect to U. S. Veterans' Hospital No. 81, which is now called the Bronx General Hospital, is this: It happens that I have been consulting surgeon up there for more years than I would like to admit, and I would like, in a way, to draw a comparison of the pre-Hawley and pre-Magnuson days with the post-Hawley and post-Magnuson days, and I am afraid that all I may say of the past is not entirely complimentary.

When I first went to the Veterans' Hospital, it was a hospital of 1,200 beds. It now has 1,800 beds. It was manned by Veterans' Bureau men, who were civil servants. They came at nine and they left at five. When it was a 1,200-bed and later an 1,800-bed hospital, they had only two doctors on duty at night and over weekends. These two were not surgeons because they had to learn the details of admitting veterans. At that time, we had some swell surgeons up there, men who were in the Veterans' Bureau, but the system bogged them down.

I became very much perturbed about this situation, because it did not seem fair to me to have men do major operations, then have their extra time taken up with paper work so they could very rarely see their patients. There was a higher mortality than there should have been. Therefore, I went to Dr. MacEachern of the American College of Surgeons and I said, "You ought to send your hospital representative to the Veterans' Hospital to see if something cannot be improved, and if it cannot be covered by more men." He said, "You write a little note and put it on my desk."

I took a piece of scratch paper and I wrote, "Dear Mac: There are only two officers on duty, officers of the day, at the Veterans' Hospital over weekends and at night, and the mortality over weekends would cause a riot in the ordinary American civilian hospital." Well, Dr. MacEachern took that note in my handwriting and put it on Dr. Hines's desk, and Dr. Hines sent it with a caustic note to the Veterans' Bureau manager at the Bronx Veterans Hospital, and I was called on the carpet. However, it was worth while, because I did get six men, three of whom were surgeons, on duty at night and over weekends during this attack. Now we have fifty residents for these periods

During my early time at the Veterans' Hospital, there was the most beautiful isolationist practice you ever saw. I wanted to get Dr. Allen Whipple to come up one day and make surgical rounds. I went to the manager and he said, "These boys are patients of the United States Government; they should not have anybody seeing them besides their own doctors, and they should not be made clinical examples." One would almost have needed a special Act of Congress to bring a visitor up there to make rounds.

The manager would not allow the younger men to go to meetings or to take special courses in New York City because he said these men were serving the boys of the Government, they were paid to serve the boys, and they could not have time off to do any foolish things like that.

That is what it was like before the present era.

Right here, I should like to pay a tribute to what has happened, because I have seen it happen and I have seen it happen after having tried for years and years to make the change. You all know what they are doing and it is unnecessary for me to tell you, but I would like to say a little bit about our experience in New York.

In the first place, the Deans' Committee appointed the senior surgical consultants and they did it by making all of the past consultants resign and then they appointed the men whom

they thought best fitted to carry out their new program. It was the job of the consultants to recommend to the Deans' Committee the various attendants.

We have never had one political suggestion that we appoint a man as an attending surgeon or attending physician. It was left without any political suggestion to the consultants, and the consultants' only trouble was that the Deans' Committee might not approve or not think they were doing as well as they should. But so far as the Veterans' Bureau was concerned, there was no political interference. It was the same way when we started our Resident Program. That was a heartache to all of us. In general surgery, I think we had about 110 well trained veterans who wanted twenty jobs, and it was an awfully tough job to turn down over a hundred men and try to pick, with as little knowledge as we had, those whom we thought were the best men. Nevertheless, there was no influence from any source brought to bear on us, and I persuaded the Deans' Committee that they appoint Dr. Whipple and Dr. St. John also as senior consultants at the Bronx General, and all of us, if we fail, fail because of our inability to judge men or inability to chart a program and not because we have had any political bonds put on us in any way whatsoever.

I think that at the present time, we have established in this hospital—and I know that any number of you men have in others—a good resident teaching system. The men who are preparing for their Boards are freed from clinical work so that they can take the basic sciences, and the others are being well trained in clinical surgery. I saw a senior resident the other day who, by himself, had done a complete gastrectomy and had done a beautiful job. We are trying to teach them honesty in surgery in that once a week Dr. Whipple, Dr. St. John and I, in general surgery, have a conference in which each surgical division tells of its list of operations, the interesting cases, the casualties, infections and complications, and we hold them pretty definitely to it. We finally have gotten them to the point where they will admit errors in diagnosis, which is very difficult to do, even to where an error is made between direct or indirect inguinal hernia.

We think, therefore, we are starting a program which we hope that Dr. Hawley approves. I heard indirectly that Dr. Whipple, who, as you know, was Professor of Surgery at Columbia, said the other day that he thought the best resident training in New York was at the Veterans' Hospital.

Ladies and gentlemen, I give you General Hawley, who is responsible for all of it!

ORGANIZATION AND CARE OF BATTLE CASUALTIES

MAJOR GENERAL PAUL R. HAWLEY
Washington, D. C.

I DO not think it is necessary to explain this laryngitis which is a matter of about twelve hours, but I am as sorry for it as you possibly can be.

This, fortunately for me, seems to be Cincinnati Night, what with Ralph Carothers, and the man who taught me all the surgery I know —my good friend, Hegner, here—which is the reason why I never made a surgeon out of myself, and myself—all from the University of Cincinnati. More power to us and may this happen more frequently!

But I think, in all honesty, we should correct some remarks. Dr. Carothers said that he was one of the organizers of this Society, and had never hoped to be President. Well, that's bunk, of course. Nobody ever worked to organize a medical society without knowing that eventually he was going to be made president.

I did say, while I was sitting here and eating my dinner, and I said it seriously, that I think this is one of the most important societies in American medicine because trauma is certainly the most important universal thing which confronts every surgeon, and it is becoming more and more important in the field of surgery.

As regards the progress of the Veterans' Administration in the past eighteen months, I want to say very frankly that we are still very short of our goal. We have made progress and the progress we have made has been due to the great men in the profession who have come to us, full time and part time. I shall not attempt to mention them. I have met so many here tonight that if I attempted to enumerate them, I should forget someone. But I should like to mention the men at the head table, Dr. Bancroft, on part-time, who has taken so much on his shoulders in the Bronx, and Paul Magnuson, who is the spark plug in my own central office organization. And then I could go down the line and pick people that I am proud of, and that I know you are proud of; and such progress as we have been able to make has been due entirely—I would say entirely—to the contributions of those people.

Those of you who have been forced into medical administration—and I was one; I practiced medicine for seventeen years in the Army until I was forced into administration—those of us who were forced into administration realize that our only reason to be is to give the sort of administration which will exploit to the fullest the great medical talent in this country.

Two nights ago, I had to speak before a symposium which was organized by the Surgeon General of the Army, and which brought to Washington some very distinguished people in the American medical profession. I gave, I am afraid, a rather unpopular talk; in fact, I considered myself fortunate that the listeners did not start throwing water tumblers at me before I left. But the entire theme of my talk was that never in the history of our country (and I think this is true of any country) have we in the Regular Army given a quality of leadership comparable to the great quality of professional talent that comes into the Army in time of war. And since circumstances force us in the Regular Army to plan the organization best to exploit this talent, it behooves us, before the next war, to develop a system which will train the Regular medical officer to give the kind of leadership—well, leadership is a bad term—to give the support and the organization that the great profession of the country deserves, when it comes into the Army; and I hope we can do that.

Now, I would be presuming if I attempted to talk to you tonight technically upon the surgery of trauma, notwithstanding the great efforts of my friend, Dr. Hegner, to make me a surgeon. If I were a surgeon, I could draw heavily on my observations in the European Theatre and perhaps make a rather learned speech upon the technic of the surgery of trauma. But it would be entirely from observation, and I should like to talk to you briefly about the organization which is necessary in the care of trauma in large quantities.

There are three essential elements in the care of battle casualties: The first is personnel; the second is equipment; and the third is supply. If you have those three elements in adequate

amounts, you can treat all the battle casualties in the world.

However, none of these essential elements is of much value alone; and to be effective, all three must be coordinated through organization. The amount of organization required is in direct proportion to the daily casualty rate. Where casualties are very few in number, as in the case in the average civilian experience, little organization is required other than a hospital and its staff and an ambulance to call. Any more complex organization than this for the purpose of speeding the patient to the surgeon would be uneconomical. Facilities would be idle for hours and days, waiting for something to happen.

However, when casualties are occurring at a rate in excess of 5,000 a day, a plan of such simplicity is of little use. In the first place, casualties occur in places where it is impossible to telephone for an ambulance. In the second place, they occur in such numbers that it is impossible to provide enough ambulances for individual calls, and such ambulances as are available must carry several patients each trip. This makes it necessary to collect in groups casualties near the front, so that all ambulances may be filled promptly.

In the third place, hospitals cannot be located as near the scenes of injury as they can in metropolitan areas, and there is often a considerable time lag between injury and surgical attention during which emergency care and treatment must be provided at all times.

In the fourth place, because there is always some limit to the surgical talent available, and because casualties occur more or less at irregular intervals, it is not always possible for the surgeon to attend each patient the moment he arrives at the hospital, and some degree of organization is required, both for the sorting of cases according to their urgency and for the support and care of those who must wait for treatment.

In many respects, the immediate first-aid treatment given a battle casualty is the most important of all the treatments that he gets. If effective first-aid treatment is not immediately available, a considerable proportion of battle injured will die rather promptly from hemorrhage or from shock, and the wounds of a larger proportion will become dangerously infected before they can be properly cared for in a hospital.

Now, prior to World War I, there was a very limited unit medical service in our Army, and the British went through World War II with the type of unit medical service which we used in our Army in the Civil War. This limited unit medical service consisted of a doctor and one or two enlisted men of the Medical Department with each combat battalion or similar unit of the fighting forces, whose function it was to establish a first-aid station at a short distance behind the firing line. Combat soldiers were somewhat perfunctorily trained in first aid, and litter bearers were detailed from the combat troops.

This system has several basic defects: In the first place, since the greater part of the training of combat troops must be devoted to their business of killing, it is never possible to train combat troops as well in first aid as it is a medical soldier to whom this is his principal business; so the training of the combat soldier in first aid has never been fully satisfactory in our Army or, I think, in any army. In the second place, certain first-aid technics, such as the highly important one of applying a Thomas splint, are so difficult that they require long training and constant practice, and this is too much to expect of a combat soldier.

In the third place, unless litter bearers are well trained, casualties are often handled very roughly, which not only adds to their discomfort but also invites the onset or the increase of shock. There are also the disadvantages to the combat troops with such a system. The detail of combat soldiers as litter bearers reduces the fire power of the unit and encourages skulking and straggling.

And so, prior to the first World War, the unit medical service of our Army was increased to provide not only for a detachment to operate the unit aid station, but also for litter bearers at the front. However, still under this augmented system in the first World War, the combat soldier was relied on to administer his own first aid prior to the arrival of a litter squad.

Now the recognition of the importance of immediate first aid, expertly applied, and of the impossibility of attaining this with combat soldiers, prompted further expansion of the unit medical service of our Army before this last war, to include a first-aid man in the Medical Department for each combat platoon. These company aid men, as they were designated, while assigned to the unit medical service, were

attached to the platoons that they served; and they lived and they died among the combat soldiers. Expertly trained in first aid, as brave as the bravest, they did a magnificent job in the European Theatre. They saved thousands of lives, and their ministrations under fire on the battlefield were no small contribution to the great reduction in the fatality of battle wounds during this last war.

Some 2,500 of these splendid medical soldiers were killed in action, and approximately 10,000 were wounded. They were awarded decorations for valor out of all proportion to their numbers. Many received the Distinguished Service Cross and at least one, and while I am not certain, I think there are now two were given the Congressional Medal of Honor. The medical profession should be very proud of these fine soldiers.

Except for modifications made necessary largely by improved means of transportation and, to a lesser degree, by the different tactics employed in this last war, the basic organization of the remainder of the medical service of the European Theatre was the same as in the first World War. One heard much talk early in the war that radical changes in medical organization were necessary to meet the changes in armor and armament and the increased mobility of the combat troops. Where such radical changes were tried, the results were poor; and the experience of this war proved, to my satisfaction at least, that the old and established principles of casualty evacuation are as sound today as they were in the Civil War, during which they were developed, and that it is only the application of these principles that must be modified to meet the changing conditions of combat.

Prior to this war, it was a rather fixed principle that evacuation hospitals must be located at a rail head or other forward terminus of a transport system. In Europe, in this war, the rail lines were so damaged by our own Air Force that they could not be repaired as rapidly as our Armies advanced, and motor transport had to be used for great distances to supply the troops near the front. To have located evacuation hospitals always at rail heads would have placed the great majority of them so far to the rear that they would have been useless for the early definitive treatment of casualties; so they were located to be of best service to the troops. Ambulance evacuation supplied the link between them and the rail heads when rail transport was used.

The use of air evacuation made necessary the location of evacuation hospitals, or field hospitals substituted for evacuation hospitals, adjacent to such air fields as were designated for air evacuation. However, and here is the important point, the *basic* principle which had been established years before was not that the evacuation hospital must be located at the rail head, but that it must be located where casualties must be collected in considerable numbers in order to fill transports of larger carrying capacity, such as a hospital train. As both air transport and convoys of ambulance companies provide transport of large carrying capacity, the basic principle of the location of evacuation hospitals was observed in the European Theatre.

It must be remembered only that the evacuation hospital *receives* its casualties in single ambulance loads from scattered units on the front, but that it *evacuates* its casualties in large lots to one single destination in the rear, usually to a fixed general hospital; and this is the consideration that governs the location of an evacuation hospital.

Now, to summarize, the principles of the care, of the treatment and of the evacuation of battle casualties that were followed in the European Theatre, were these:

First, the prompt and effective first aid at the very spot at which the soldier was wounded, administered by a well trained soldier whose only duty this was.

Second, the removal of the casualty from the field to a unit aid station as promptly as possible, under his own power if he could walk without danger, and by a trained litter squad when he could not walk without danger.

Third, professional attention at the unit aid station limited to emergency treatment to save life or limb, and to support the patient until he could reach the next station to the rear.

Fourth, evacuation to the division clearing station by ambulance, where it was possible to get the ambulance to the aid station; and, otherwise, further litter carry to a collecting station where ambulances were loaded.

Fifth, a more thorough examination at the clearing station. If in urgent need of surgery, immediate transfer to a field hospital located hard by the clearing station, where an expert surgical team was always on duty. If able to

stand further transportation before surgery, evacuation by ambulance to an evacuation hospital, some ten to twenty miles to the rear where expert medicine and surgery were always available.

Sixth, after recovering from any necessary emergency surgery in the evacuation hospital, or when able to travel without surgery, evacuation by air or by rail to a general hospital many miles behind the front line. It is evident that the average casualty passed through at least three medical units where he may have received treatment before he arrived at a general hospital in the rear, and that the more serious cases were sent back to the United States for completion of their definitive treatment.

Now, this change of hospitals and of surgeons created a problem that is not often encountered in private practice in the case of traumatic injuries. This was the problem of insuring continuity of the same method of treatment throughout, or at least as long as the patient was in the European Theatre. In private practice, the surgeon ordinarily receives a patient at once in the hospital and cares for him until he recovers. Take the treatment of fractures, for example, some surgeons prefer one method and some another. Some are expert in one method; others are not. But when several surgeons in turn undertake the care of one patient with a fracture, it is important that each follow much the same method; and, to make this possible, the method must be prescribed and it must be one that every surgeon is capable of following, whether or not it is his own method of preference.

For example, some surgeons prefer the Roger Anderson apparatus in the treatment of selected fractures of long bones. In the hands of surgeons experienced in the use of this apparatus, it is undoubtedly efficient. But the majority of our surgeons in the European Theatre had never used a Roger Anderson apparatus. Others of our surgeons came to Europe preferring internal fixation in the majority of fractures of long bones. But not all of our surgeons were experienced in this method; so we prescribed suspension traction for the routine treatment of fractures of the femur, for example, because this was a tried and proved method familiar to all competent surgeons. Most of our surgeons recognized the necessity for such restrictions and accepted them graciously, even if they did not always agree that the methods we prescribed were the best methods.

So much for the general organization for the care of battle casualties.

We can dismiss equipment with a word. In general, our equipment was ample in quantity and first-class in quality. I cannot remember ever hearing a real complaint about the medical and hospital equipment furnished to our Army. A few ingenious improvisations here and there added to its efficiency, and some of these improvisations will undoubtedly be manufactured and supplied in the future.

The other important element in the care of casualties is supply. I think that no medical officer who served in the European Theatre would dispute seriously my assertion that our medical supply was the finest in the history of warfare. This is not to say that every medical officer at all times had every gadget that he would have liked to have had; but it is to say, rather, that no hospital was ever handicapped by a shortage of essential supplies.

The organization for supply was a difficult and intricate task. Medical supplies are small in bulk and were usually shipped from the United States as what was called "filler" cargo, together with shipments of arms, ammunition, engineering materials and vehicles. They were put in the cracks and crevices between the heavy materials that had to be shipped in the holds of ships, so that they arrived scattered among many shipments which were unloaded in many ports at different times. Now, at times, supply ships were backed up in harbors to the number of several hundred, and they were unloaded on a priority basis determined by the need for their principal cargoes. For example, a ship might be loaded with 10,000 tons of bridge materials and 100 tons of medical supplies. If there were no immediate need for the bridge materials, the ship would not be unloaded regardless of our need for the medical supplies that were aboard. Occasionally, if our supplies could be got at easily, we could get them off such a ship by lighter, but that was the exception rather than the rule.

While at first all of our medical supplies were unloaded in England, as soon as the French ports and the Belgian and Dutch ports were opened, some were unloaded in one place and some in another, and we never knew when a ship came from the States in which port it would eventually be unloaded.

Supplies had to be consigned to the various depots from the ports, and we had eighteen or twenty medical depots throughout the theatre; so it required a high order of ability and industry to keep the large stocks balanced in all depots at all times, with the incoming supplies arriving all over this part of Europe.

Then there was the problem of medical supply for the initial landings on the Continent. No one knew how many ships would be sunk in this difficult attack, or what ships would be sunk. We expected terrific casualties among these ships. We expected to lose a large number of ships in this first attack on the Continent.

Had supplies been sent in this attack in their original classified containers, such as we received them—which were boxes of dressings, boxes of morphine, cases of ether—had we just taken those and attempted to ship them across to the Continent during the landing, when one ship went down it might have carried all of the dressings that we had, or all of the ether or all of the morphine; and so, to prevent such a disaster, we repacked our medical supplies in large waterproof units on skids—something like the farmer's sled that he uses to haul water out to his hogs—and I hope all of you know what a hog is, since I have been identified with it. We had la ge skid loads of supplies that could be hooked to a truck or tractor and dragged; and by test, we found that we could dump them in the ocean and for three days there would not be a bit of leakage. We could salvage them from under the water, completely submerged, and the dressings would be dry and nothing else spoiled. And so we repacked all our medical supplies for the invasion on these unit skid loads.

Each one of those unit skid loads contained a balanced stock of drugs, dressings and other things needed for the treatment of 1,000 casualties of all kinds. We estimated how much of this and of that would be necessary to treat 1,000 assorted casualties—how much morphine, how much ether, how many dressings, how much castor oil, for example, or how much salts—and we packed those in unit loads.

And so with this system, if a ship went down with skid loads on it, there was no one item lost in its entirety, and every skid load that got ashore carried a balanced stock of all of the essential items. When we got word of the sinking of a ship that had ten skid loads on it, we had only to put ten more skid loads on the next ship that went over and thus we always had a balanced stock of medical supplies on the beaches.

This was an improvisation which we developed over there largely as the result of the work of my own supply officers. And speaking of improvisations of that kind reminds me of a story which I will tell, with due apologies to several of my friends who have heard me tell it before; but since my stock of stories which can be told in an audience of this kind is rather limited, I shall have to repeat it.

Remember that this is a story of improvisation. This is the story of a British Land Army girl who had been raised in London; and, when the call came to go out and work on the farms, these Land Army girls did a perfectly magnificent job. This girl went out on a farm. She had never seen a farm or a hog or a cow; and many of the chores that she had to do were quite a trial to her. She had a lot of learning to do.

She went to the village "pub" one night with a group of friends and stayed longer than she was accustomed to, and drank more beer than she was accustomed to, and went home very late. She had to get up the next morning at the usual time of four o'clock. She got up with a headache and a bit of a hangover; and, feeling very badly, her first chore was to milk the cow. She went out and, never a very good milker and with an extra handicap this morning, she was making very heavy weather of milking the cow and not getting very much milk. Finally the cow became discouraged and turned around and said, "Now, never mind, dearie, I know just how you feel. You just hold on, and I'll jump up and down."

To me, the distribution of fresh whole blood was the most dramatic accomplishment of medical supply in the European Theatre. In common with the majority of the medical profession at the outset of the war, we had the impression that reconstituted plasma was an acceptable substitute for whole blood in the majority of cases of trauma. British reports of the fighting in the desert confirmed this opinion of ours. Consequently, our original plan was to furnish about one pint of whole blood to each five pints of plasma at the front.

However, our small experience with Air Force casualties in 1942, when we were only fighting in the air in Europe, led us to increase the proportion of blood in our supply plan; and our blood bank in England was set up initially

to furnish about three hundred pints of whole blood daily. This, we estimated, would furnish about one pint of blood to each three pints of plasma used. However, as soon as we landed in France, the demand of our surgeons for whole blood was much greater than we had anticipated.

I went personally to the front to see whether or not our surgeons were calling for whole blood when plasma would have sufficed. I was soon convinced that no more blood was being used than was necessary, and that in many cases plasma was not an acceptable substitute for blood. We immediately doubled the capacity of our own blood bank in England, but it was evident that between 700 and 750 pints per day were the ultimate limit of the possible production in the European Theatre.

We were collecting this blood largely from supply troops. We collected very little from the British civil population, because the British had a blood bank program which was taking most of the blood from their civil population; and so we had to depend upon our supply troops in the back areas. But, as our supply lines got longer and longer, with the same number of troops, the supply troops became thinned out, and it was very difficult to get very much blood in any one place; and this difficulty of collection of whole blood among our troops limited the amount of processed blood which we could produce in our own blood bank.

As the strength of our forces was constantly increasing on the Continent, we could see where our own production of blood would satisfy less than half of the demand for whole blood; and so General Elliott Cutler flew back to the United States and arranged for the shipment by air daily of a thousand pints of whole blood from the States. And this, together with our own production, gave us a daily supply of some 1,700 pints of whole blood. This proved adequate, but never excessive.

Blood was distributed to forward blood banks by air, in iced containers of the thermos-bottle type; and from these forward blood banks the field and evacuation hospitals received it by motor transport.

Rarely was a hospital out of blood, and then only for a few hours during which they were able to obtain plenty from volunteer donors on the spot.

Now, one of the first, the very first, vehicles that went ashore on the Normandy beaches was a refrigerator truck of our own blood bank; and, with the beach swept by enemy fire, the driver of this blood bank truck persuaded an engineer soldier on a bulldozer to dig a foxhole in the sand large enough to submerge the entire refrigerator truck; and there our truck stayed, right in the middle of the battle on the beach head, supplying the field units around it with all the blood that they needed.

I have not touched upon the organization of general hospitals for the reason that they are quite similar to those in civilian practice. However, there is one more important element that must be taken into consideration, and that is that the great number of general hospitals required results in a shortage of certain critical specialists. In the European Theatre, there were never nearly enough competent ophthalmologists or neurosurgeons, for example. Fortunately, our original plan had located general hospitals in centers of six to twelve general hospitals in one area, and we could place one of these critical specialists in one of the hospitals of the center, and then sort our cases in that specialty all to be sent to that one hospital, in the interest of best utilization of professional talent.

Now, before I close, I want to offer a suggestion for the better utilization of expert professional personnel at the front in the next war, if we are so unfortunate as to have one. At any one time, certain hospitals at the front will always be swamped with casualties and others in the quieter sector will have very little to do. Also, after an attack has moved on and there are no new admissions to a field hospital, its work until it is able to close, is limited to after-treatment of the patients who have been previously operated upon; and the need for expert surgeons is thereby greatly reduced. These facts point the need for the greatest possible flexibility in the organization of the professional personnel at the front. Some of this flexibility was furnished in this war by the auxiliary surgical groups, one of which was assigned to each Field Army. From these groups came all the surgical teams that did the surgery in the field hospitals, and which reinforced evacuation hospitals whenever they were overloaded.

Now, this was fine so far as it went, but there still was a lot of fine surgical talent that was frozen in the fixed Tables of Organization of

evacuation hospitals and which, in my opinion, could have been used more effectively if it also had been in the auxiliary surgical groups.

Then there was the need for other teams, such as teams specially trained in after-treatment, which could have relieved the surgical teams in field hospitals after all the surgery had been finished and the patients were convalescing, to the point where it was safe to evacuate them to the rear.

And so, I would take most of the professional talent out of the evacuation hospitals and place it in auxiliary surgical groups, leaving only the chiefs of service and a skeleton professional organization in the permanent unit; and I would attach professional teams, medical as well as surgical, to the evacuation hospitals in accordance with the needs at the moment.

In conclusion, I would repeat what I have often said in public, that the work of the American physicians and surgeons in this war was simply superb. I am terribly proud of the American medical profession. But this vast reservoir of talent would have been largely wasted had there not been an organization which could properly exploit it; and so, for the proper care of battle casualties, the essential elements are good doctors, good equipment, good supply, and last but not least, a good organization that will bring these three elements together with the patient before it is too late to help him.

TREATMENT OF FRACTURES OF THE OS CALCIS BY OPEN REDUCTION AND INTERNAL FIXATION

ALFRED H. WHITTAKER, M.D.
Detroit, Michigan

OUR thinking concerning fractures of the os calcis can be expressed in the form of a syllogism, the major premise of which is, "in fractures of the os calcis anatomic reposition cannot be obtained," the minor premise that "without good anatomic position function is impossible," thus the conclusion being that "in fractures of the os calcis it is impossible to obtain good function."

This attitude will be borne out by reviewing our own cases, or by asking any surgeon what his results are in so far as function is concerned, or by noting the number of contributions appearing in the literature during the past ten years, bearing the title "a new method of treating fractures of the os calcis," or by the statement of Willis C. Campbell that "malunion in fractures of the os calcis is so common as to be almost the usual result."

This attitude culminated this past year when Kenneth H. Pridie of Great Britain advocated the excision of the posterior tuberosity in comminuted fractures.

The high percentage of permanent partial disability has been one of our most distressing problems and in an effort to obtain a solution we have now reduced three fractures by open reduction and have maintained the reposition by internal fixation with results which I suggest refute the conclusion of the syllogism which I previously stated.

The os calcis is fractured more frequently than any of the other tarsal bones and in various series these fractures comprise 1 to 2 per cent of all fractures.

ANATOMY

There are several considerations of the anatomy which are helpful in planning the treatment and which add to an understanding of the fracture.

There are five articular surfaces, each one playing an important part in carrying the body weight in certain positions, in permitting motion and in adapting the foot to certain positions. For example, the subastragaloid joint permits lateral tipping of the foot to adjust it to uneven surfaces. Thus an arthrodesis results in a disability for walking on rough on uneven floor or ground.

The bone is largely cancellous in structure, the outer surface consisting of a thin, brittle cortex. The spongy structure provides an elasticity in weight bearing. It is dense enough to contain and hold a screw or nail used as internal fixation.

To the inner side is a shelf of bone called the sustentaculum tali which provides an attachment for the medial ligaments of the ankle joint and support for body weight, and at its anterior portion provides insertion for the inferior calcaneoscaphoid ligament which adds support for the mid-tarsal region and springiness in walking.

The upper surface of the tuberosity runs obliquely downward from the edge of the posterior subastragaloid articulation, and lines drawn from this point anteriorly to the anterior rim of the anterior subastragaloid articulation, and posteriorly over the superior surface of the tuberosity will bisect to form an angle of 40 degrees. This is known as the tuber-joint angle. In the typical comminuted fracture the two lines become parallel, and a restoration of the normal angle is essential if a good reduction is to be obtained.

The depression of the sustentaculum tali when fractured carries a portion of the medial ligaments forward, a portion posteriorly, thus exposing the subastragaloid joint and permitting reduction at operation under visual control of the articular surface.

In 1940, Arthur Steindler stated that: "In fractures of the os calcis, the disability may be not so much to malunion as to the indirect effect of the fracture upon the lateral balance of the foot, due to involvement of the subastragaloid articulation and the traumatic arthritis which develops. The tendency to joint disintegration is lessened by good anatomical reposition. If pain persists, however, the treatment is a subastragaloid arthrodesis."

Because of the difficulty of complete reduction by closed manipulation, some clinicians perform an immediate arthrodesis of the subastragaloid joint and some add an arthrodesis of the calcaneocuboid joint.

CLASSIFICATION (KEY AND CONWELL)

1. Avulsion fracture of the tuberosity or separation of the apophysis.
2. Fracture of the medial and lateral processes of the tuberosity.
3. Isolated fractures of sustentaculum tali.
4. Fractures of the body of the os calcis.
    a. Fracture with eversion of the tuberosity.
    b. Fracture with upward displacement of the tuberosity.
    c. Telescoping fractures with lateral mass driven up under the external malleolus.
    d. Comminuted fractures into the subastragaloid joint.
    e. Comminuted fractures of the anterior portion of the body into the calcaneocuboid joint.

To the above listed types should be added the more recently recognized march type of fracture. This is characterized by a painful heel, a line of healing being distinguished after several weeks by x-ray study, the line of fracture not extending through the cortex.

PATHOLOGY OF FRACTURES OF THE BODY OF THE OS CALCIS

Due to the fact that when the foot strikes the ground it is usually pronated with the tuberosity of the os calcis directed outward, backward and downward, and that it tends to be carried upward, outward and forward permitting the sustentaculum to be displaced downward and the long arch of the foot to be flattened, there is usually an oblique fracture line through the tuberosity which communicates with verticle and transverse fractures. This main transverse line extends in a more or less horizontal direction across the posterior portion of the body and tends to be opened on its mesial aspect, while the lateral surface of the bone is compressed and the tuberosity displaced outward.

THE FRACTURE

The typical severe fracture of th os calcis consists of a transverse fracture between the anterior and posterior processes, extending through the anterior margin of the posterior talocalcaneal articulation. This changes the line between the contour of the tuber and the subastragaloid joint, the tuber-joint angle.

One or more longitudinal fractures of the os calcis take place, the outer taking place at the outer aspect, extending forward to the cuboid, the inner fracture extending through the inner portion, extending forward to involve the sustentaculum tali.

The cortex being brittle and thin and the inner bone being cancellous, the explosive force of the fracture results in a fragmentation of the cortex, sections being rotated and driven into the cancellous portion.

The posterior process is forced laterally and forward to produce a widening of the bone and a foreshortening. The displaced cortical fragments prevent a restoration of the anatomic contour, either by traction or by lateral compression.

The anterior spicule of the lateral fragment produces the prominence beneath the external malleolus, and this is persistent even after the strongest traction by pins through the posterior process and the tibia. However, the greatest deformity can be seen on the medial aspect, and it is here that the rotation of fragments prevents reduction by closed methods.

Anatomic restoration can be obtained by open reduction through a medial carved incision, exposing the fracture. Through this incision the fragments can be replaced and the posterior process adjusted to the anterior. The fragments tend to stay reduced, but are more firmly held by one oblique screw and one longitudinal screw.

The larger vessels and nerves behind the medial malleous are far enough anterior to remain undisturbed, the plantar nerves and arteries are also anterior to the field of operation.

The complicated attachment of ligaments, the fine balance of the articular surfaces to carry the stress of the body weight in various positions, the proximity of synovial tunnels to transmit tendons, and the strength of the bone depending on an intact cortical structure, all explain the prolonged or total disability which result from only minor anatomic disarrangement.

EVOLUTION OF THE TREATMENT

The ancients made little effort to reduce fractures of the os calcis merely applying a sup-

porting bandage. In fact, very little progress was made until in 1916 Frederick Cotton suggested treatment by manipulation and impaction (Fig. 1) by pounding on lateral surface with a mallet, the foot then being placed in plaster. By 1926, Harding had devised a pressure clamp and exerted pressure on the under-

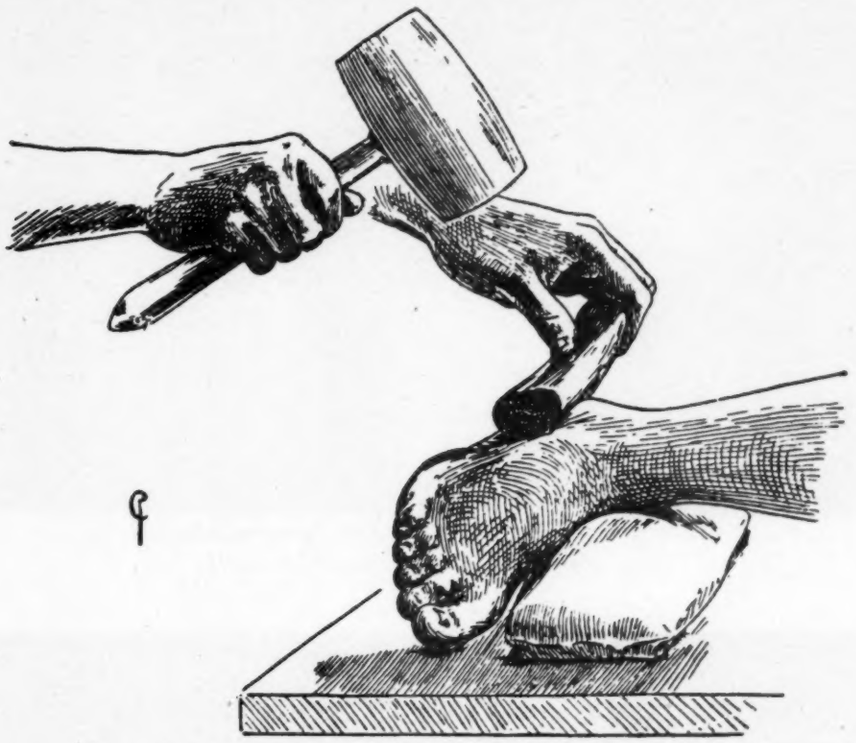

Fig. 1. Treatment by impaction (Frederick J. Cotton, M.D., 1916).

surface with a wedge. In 1927, Phillip D. Wilson discussed the value of subastragaloid arthrodesis. Robert Funsten, in 1932, described the use of a bar over the os calcis to exert traction, and, in 1934, C. R. G. Forrester offered a subcutaneous tenotomy of the tendo achilles, the use of his pressure clamp and manual molding.

The year 1937 saw the clamp of C. W. Goff designed to produce forceful manipulation, and, in 1939, Paul F. Olsen reported the insertion of Steinman pins through the tibia and os calcis, traction being exerted by means of a turnbuckle.

Two years later, in 1939, Rudolph S. Reich discussed the importance of the tuber-angle and advocated the use of a nail inserted through the skin to permit manipulation.

In 1942, J. O. Dieterley reported the use of a modified Böhler frame to permit of skeletal traction, and, in 1943, C. M. Shaar and F. P. Krenz presented a method of skeletal traction to aid in reduction, the method having been worked out with Stader. The external fixation was continued after reduction was obtained.

By 1944, Gereld G. Gill reported the use of three pins inserted with the use of the Bell table.

Thus, the proposal of a new method of treatment almost yearly reflects the difficulty encountered in obtaining good results.

OPERATION

Although the most remote portions of the human body have been entered by the surgeon, and in spite of the serious disability resulting from fractures of the os calcis, and the difficulty of closed reduction, except for reconstructive surgery in the later stages, or a disabling arthrodesis, and in spite of its accessibility, probably for fear of infection and osteomyelitis, immediate open reduction to obtain reposition has not been attempted.

The operative treatment here described has revealed that in the severly comminuted fracture, due to interposition of brittle cortical fragments and due to impaction, closed reduction is impossible. Open reduction has also made possible direct manipulation of the

FIG. 2. Fracture of os calcis with minimal displacement, March 7, 1946.

FIG. 3. Same fracture as in Figure 2 on May 22, 1946, with widening of os calcis and disability.

A B

Fig. 4. A, fracture of os calcis, January, 1946.

tuberosity, the perfect alignment of the fragments and a leveling of the articular surface of the subastragaloid joint. It has been found that this joint will accommodate a small amount of displacement, without disability, and operation reduces the joint irregularity well within the limits of function.

The operation is best performed after twenty-four hours of skin preparation before the formation of blebs, or not later than ten days after injury.

An esmarch rubber bandage is applied from the toes to above the knee over the sterile dressing, the proximal end of the bandage being used as a tourniquet. Thus a bloodless operative field results which permits of good vision.

The anesthetic used is either spinal or continuous intravenous. A curved medial incision is used, medial because it is here that the interposition of fragments occurs, and only on the inner side can the displacement of the articular surface of the subastragaloid joint be seen. The abductor hallucis muscle may be avulsed with a fragment of bone at its attachment to the medial and posterior aspect of the tuberosity, in which case it and the quadratus plantae are

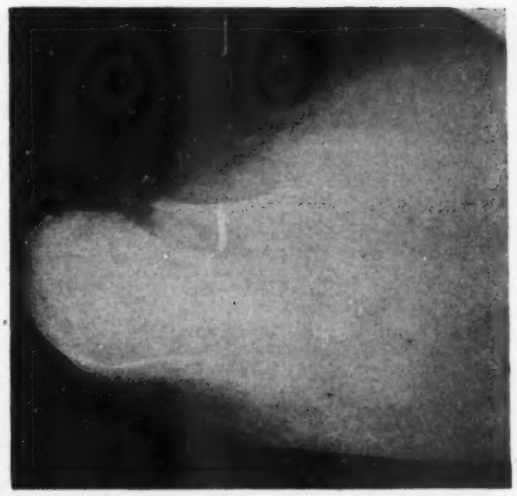

Fig. 4.B, x-ray of the os calcis at the time of the fracture revealing a typical lateral displacement of the tuberosity and interposition of the corticle fragment.

turned down to expose the medial surface of the bone revealing the fracture, otherwise it is retracted to the plantar surface. Good exposure can be obtained without disturbing the vessels and nerves posterior to the internal malleolus.

The rotated and interposed fragment of cor-

FIG. 5. Postoperative reduction with screw retention, February 24, 1946.

FIG. 6. Fracture following reduction and screw retention, April 8, 1946.

Fig. 7. Fracture, August 9, 1946.

tical bone is removed, and by grasping the tuberosity with bone-holding forceps the impaction is broken up, the fragments reduced and the tuber-angle restored.

Before releasing the forceps, drill holes are made across the lines of fracture and screws inserted which hold well. The abductor hallucis muscle and its avulsed fragment at the point of attachment are replaced and held by a screw or by sutures; the soft tissues which have been turned down under the tuberosity are replaced and closed by a deep layer of chromic catgut and the skin closed by a continuous silk suture.

A plaster mold is then applied to protect the os calcis and the tourniquet removed, no ligatures having been inserted.

END RESULTS

By the operation described, it has been possible to obtain anatomic reposition, and healing has progressed at a normal rate. The first patient operated upon, who had a severely comminuted fracture with marked displacement and extensive involvement of the subastragaloid joint, was walking well at four months and at the end of a year presents complete recovery with no disability.

Two more patients recently operated upon are walking, have excellent anatomic reposition and will probably have as good a functional result.

Not sufficient time has elapsed to determine if, in later years, a traumatic arthritis may develop, but the smooth joint surface would tend to minimize this complication.

CONCLUSIONS

General anatomic and etiologic factors have been discussed, the evolution of treatment, the pathology of fractures of the os calcis, and an operation described by which good anatomic reposition can be obtained, and thus the conclusion of the syllogism presented, that "in fractures of the os calcis good function cannot be obtained" has been disproved.

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DISCUSSION

Grover C. Penberthy (Detroit, Mich.): Dr. Whittaker, in this presentation, has provided us with something to think about from the standpoint of approaching a fracture which we all know is disabling.

He has referred to the disability as being shortened and, naturally, with the disability shortened, the period of morbidity has been shortened. In our past experience with fractures of the os calcis, we know that the disability has been long and, with the conservative forms of therapy, it has been very discouraging. Surgery, either by the subastragalar arthrodesis or the triple arthodesis, has had much to offer.

Dr. Whittaker's series is small but it is apparent from the presentation that he is convinced, after the work that he has done in the anatomic laboratory, that this procedure has merit. The photography of the operation was excellent.

I am just wondering, during the period that the operation was going on, how much attention was paid to the subastragalar joint, and that is a question, I am sure, in the minds of many: How can the subastragalar joint be so reformed or molded in such a way as not to produce a disability even after this internal fixation?

Removal of the small particles sounds very logical because, after all, such small particles of the os calcis might be a barrier to union or early union.

There are many questions that I am sure are in the minds of many, and I think Dr. Whittaker has presented this means of therapy to be, in a way, provocative of discussion, and with the result that Dr. Whittaker was able to show in that movie, I think he is to be congratulated on his courage, his ideas and his rational thinking, and it would be interesting to see, as his series increases, what the end results will be.

Homer Stryker (Kalamazoo, Mich.): I think this has been presented very interestingly and very graphically.

I, like many of you, have gone through the gamut and have treated these in many different ways and have had fairly good results and bad results with each method. I have come to think that the results were more dependent on the intrinsic factors, largely the relation between the astragalus and the fragments of the os calcis rather than to the particular method of treatment.

I recall, when I first started to practice, I treated several with the Böhler method and was quite enthusiastic about it because the anatomic results were good by x-ray, though some of them did not have too good results clinically. Then a man came in about five or six weeks after an injury. He had had no treatment and was trying to walk on his foot with crutches. I thought how sorrowful it is that he did not get to me immediately after his injury. But I hesitated to go in that long afterward. We left him alone and did nothing. I see him occasionally on the street. He has a little flatness of the foot but says he has no pain and has no disability. And, as the years roll by, I think how lucky he was that he did not get to me before that time had elapsed.

I think it has been the experience of all of you that any fracture which goes into a joint which is weight-bearing, the fragments must be accurately replaced; if there is a variance greater than the width of the cartilage, the cartilage wears away on the side that is highest and gradually a traumatic arthritis develops.

I think that in these cases, the most difficult problem is to evaluate the nature of the internal fragmentation. If there are enough large fragments so they can be replaced and held by screws, I think this offers a solution, perhaps, to some of these cases. I think perhaps in others, in which they are smashed so badly that you cannot get a good re-

placement of the upper cartilaginous surface of the os calcis—fusion may still have to be the answer.

Nicholas J. Giannestras (Cincinnati, Ohio): I would like to ask Dr. Whittaker one or two questions.

First, he mentioned that he used the medial approach to these os calcis cases, and I was wondering why he preferred the medial approach in preference to the lateral approach.

The other question is, in these os calces that are comminuted and the tuber-angle is completely obliterated, just how do you manage to realign such a fracture, which is undoubtedly badly comminuted and the articular surface is probably partially destroyed?

The third question is, what do you do as far as the piling up of bone that you see so frequently under the astragalus when you have a fractured os calcis that gives you a thick foot, or is that overcome by the open reduction?

Paul B. Magnuson (Chicago, Ill.): Of course, now that I have become a bureacrat, I have degenerated into one of the old dodos that I used to see when I was Dr. Whittaker's age and wondered how they got that way.

I have been struggling for thirty-five years with fractures of the os calcis and I am always glad to hear a new way of approaching them. It sort of pats my ego on the back because I realize that nobody has solved the problem of the fracture which I thought I had solved some thirty years ago.

I think we should go back to the fundamentals of the occurrence of this fracture. One of them is that the os calcis, or the outer two-thirds of it, lies lateral to the medial axis of the foot. Formerly these fractures always occurred as the result of a fall from a height landing on the foot. But in the Navy, it was found that the deck came up and drove them upward, which amounted to the same thing. Once in discussing a Navy program I made the mistake of referring to the deck as the floor, and was promptly corrected by Dr. Hook.

Dr. Whittaker has spoken about the widening of the heel. I do not think it makes a bit of difference what shape the os calcis is. I think it is the displacement of the fragment, the injury to the joint and the pressure mentioned by Dr. Stryker caused by the large knob of callus under the astralagus and the posterior of the external malleoleus. Now, if we are going to reduce these things, I do not think it is so necessary to reduce them anatomically because I really do not think that the shape of the os calcis has very much bearing on the matter. I think the pressure on the lateral side of the foot, the pronation of the foot because of the upward and outward displacement of the posterior two-thirds of the os calcis, the flattening of the arch which puts excess strain on the plantar fascia and the support of the foot, and the breaking into the joint are the important things.

Those fractures into the joint, I think, have a substantial part in the answer to the pain. The mechanical displacement of the heel with a consequent pronation of the foot is second.

I have severed the tendon and got more beautiful results with that and the molding than anything else, but the trouble is, when you sever the tendon, the calf muscles never come back to their adequate strength and size. But so far as replacing the fragments of the os calcis is concerned, it is absolutely ideal.

The Roger Anderson business always gave me a laugh because you put a pin through a fragment, where the os calcis may be broken into a dozen (and probably is) fragments, so it is just foolish to drill a hole through one fragment when all the rest of them are just as badly out of place as that one. If there were one solid fragment and the os calcis fractured through the neck and you could put a pin through the posterior fragment, you could probably hold traction against the upward pull of the muscles and get a good result, but that kind of fracture does not give you very much trouble anyhow, and they are very few and far between.

Phil Wilson advocated for a number of years—I have not heard him advocate it for the last twenty, I think—doing a subastragalar arthrodesis on all of them, and if I remember correctly, I said I thought they gave very good results because when you do a subastragalar arthrodesis on them, you usually replace the os calcis, move it over on the foot where it belongs, after it has been displaced; and an ankylosed joint is a painless joint. It interferes with the patient's walking on rough ground but does not give him any pain and he gets along very comfortably with it.

If there is anything that I have not tried in fractures of the os calcis, I do not know what it is, except Dr. Whittaker's method, and now that I am a bureaucrat, I do not suppose I will ever have a chance to try that. But it all goes to prove that we struggle and struggle to make something out of nothing. We come up with methods; we have a few good results, and we become enthusiastic, until we begin to get enough bad results to convince ourselves that we were not very right when we started. But if we fail to continue to try by every means in our power to make something out of nothing, then we cease to be good progressive doctors. I think this method that Dr. Whittaker has offered may be applicable in a certain number of cases carefully chosen. There is no one method that works in all of them and all the methods do not work in some of them.

Alfred H. Whittaker (closing): I appreciate the kindness of the discussers very much.

Dr. Penberthy asked about the reformation of the subastragaloid joint and what attention was given to that. As I mentioned, the ligamentous structures are displaced when the sustentaculum is

depressed, and it gives a view into the joint surface which is not obtainable with the lateral approach to the subastragaloid joint; and by manipulation with a bone forceps, it is possible to get a very smooth subastragaloid joint. In these cases today, I would like to stress that I am talking about the severely comminuted, the really bad fracture that gives trouble, not the one we do not have to do anything for.

Dr. Stryker and Dr. Magnuson both stressed the importance of the fact that they should be selected cases, and I appreciate that. It is, of course, not every fracture of the os calcis that should receive the type of treatment we are dealing with here today, but I do believe that the more severe the fracture, the worse the displacement, the greater the possibilities of reduction under direct observation.

Dr. Giannestras asked about the medial approach. To explain that, all of our approaches to this fracture in the past have been through the lateral surface, and we have been doing that in order to do something about the spicule of bone on the lateral surface, about which so much callus formation takes place and which really encroaches on the subastragaloid joint at times and produces a certain part of the disability at least; we have forgotten that on the medial surface is where there is even more marked displacement, the tuberosity having been driven up, and the fragmentation of the cortex turning these fragments in between the two larger fragments in the medial surface. Our medial approach permits us to do the one thing that allows a reduction, and that is the removal of the interposing fragment which is blocking reduction and in all three cases that we have done, that has been there as an absolute mechanical blocking to reduction.

Dr. Giannestras also asked about what method we used in correcting disturbance in the tuber-angle. Well, if you noticed in the film, you could see that the manipulation with the bone forceps elevated the sustentaculum, made a smooth surface of the subastragalar joint and corrected anatomically the disturbance in the tuber-angle. I have never been able to do that by closed reduction. We have been able to do it each time by having the bone fragments directly under our control.

Dr. Giannestras also asked about this piling up of the bone on the outer surface. Well, there is no piling up of bone on these, as shown by the follow-up x-rays in these cases, because we have reduced that spicule which sticks out so far in the ordinary fracture of the os calcis. That spicule is not sticking out there to result in piling up of callus on the outer side of the os calcis. Therefore, we do not have that widening of the bone to deal with in our trying to get a functional result later on.

Dr. Magnuson mentioned the position of the fragments and the flattening of the arch, which is a problem, of course, we are trying to solve here. Personally, I believe that being able to get a good anatomic position does correct the disturbance in weight-bearing, does correct the thickening of the bone, and the only importance of the thickening of the bone is that that thickening is due to a piling up of the callus below the external malleoleus and also due to the impaction of the fragments, which we break up and get a full-length os calcis instead of these foreshortened bones which are wide and which in themselves block mobility.

Therefore, I believe that the reposition of these fragments anatomically is of tremendous importance if we are going to get a good anatomic result.

We, too, have carried out arthrodesis over the years, and I believe that in an active man who has to make a living, who has to get about all day long in his daily work, when we do a subastragaloid arthrodesis, we are taking at least part of his ability to function well away from him, and while there are undoubtedly cases, especially old cases, in which that is the final solution and it does do away with the painful joint, it still contributes so much disability to an active man, especially in the middle years of his life, that if we can avoid an arthrodesis, I think we should do so, by all means.

THE USE OF INTERNAL FIXATION IN COMPOUND FRACTURES*

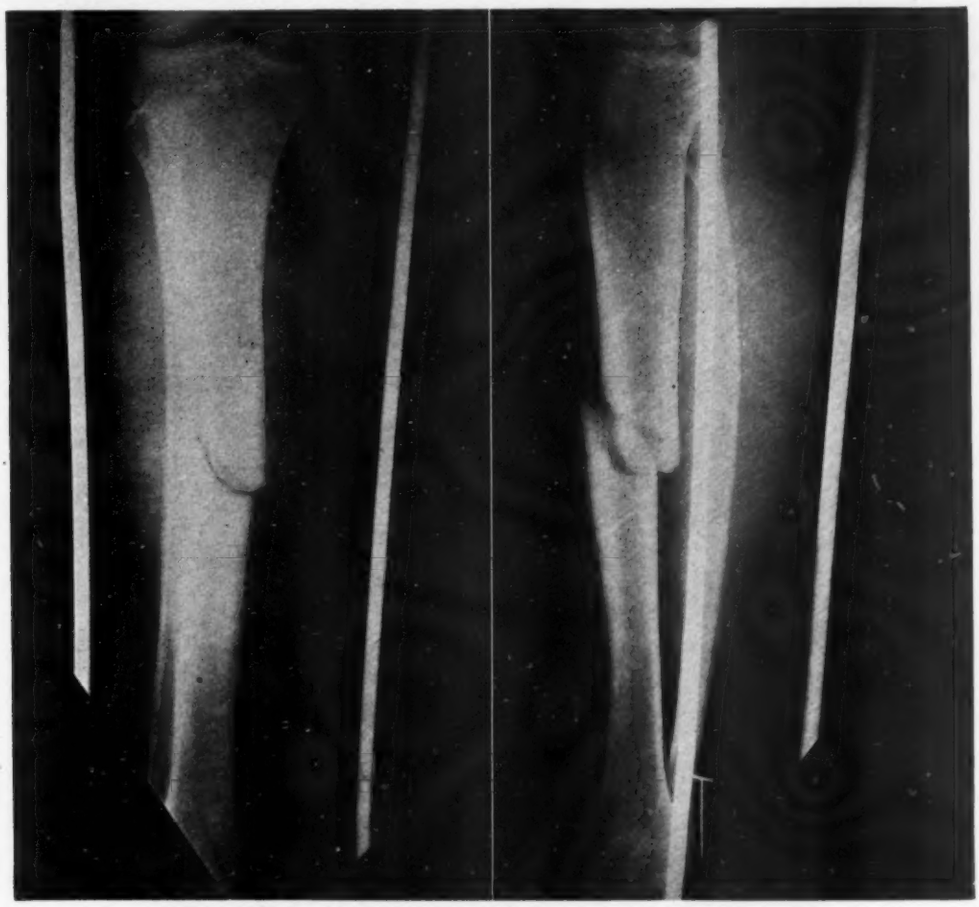
BARBARA B. STIMSON, M.D.

Assistant Professor of Clinical Orthopedic Surgery, College of Physicians and Surgeons, Columbia University; Associate Attending Surgeon, Presbyterian Hospital and Vanderbilt Clinic

New York, New York

COMPOUND fractures can be plated. Whether they should be so treated is still a matter for debate. Many arguments for and against have been heard, especially during the war years, and it seemed wise to see if impressions could be substantiated by facts or if a revision of these impressions was necessary.

With this purpose in mind an analysis has been made of the compound fractures of the shafts of femur and tibia treated on the Fracture Service of the Columbia-Presbyterian Medical Center for the years 1932 through 1942 inclusive. As there is no ambulance service for the hospital the number of such cases from 1932 through 1941 is small. In 1942, a study of com-



A B

FIG. 1. A and B, original injury, compound fracture.

* From the Fracture Service of The Presbyterian Hospital and the Department of Orthopedic Surgery, College of Physicians and Surgeons, Columbia University, New York City.

C D

E

FIG. 1. C and D, post-plating; note transfixion screws; E, result.

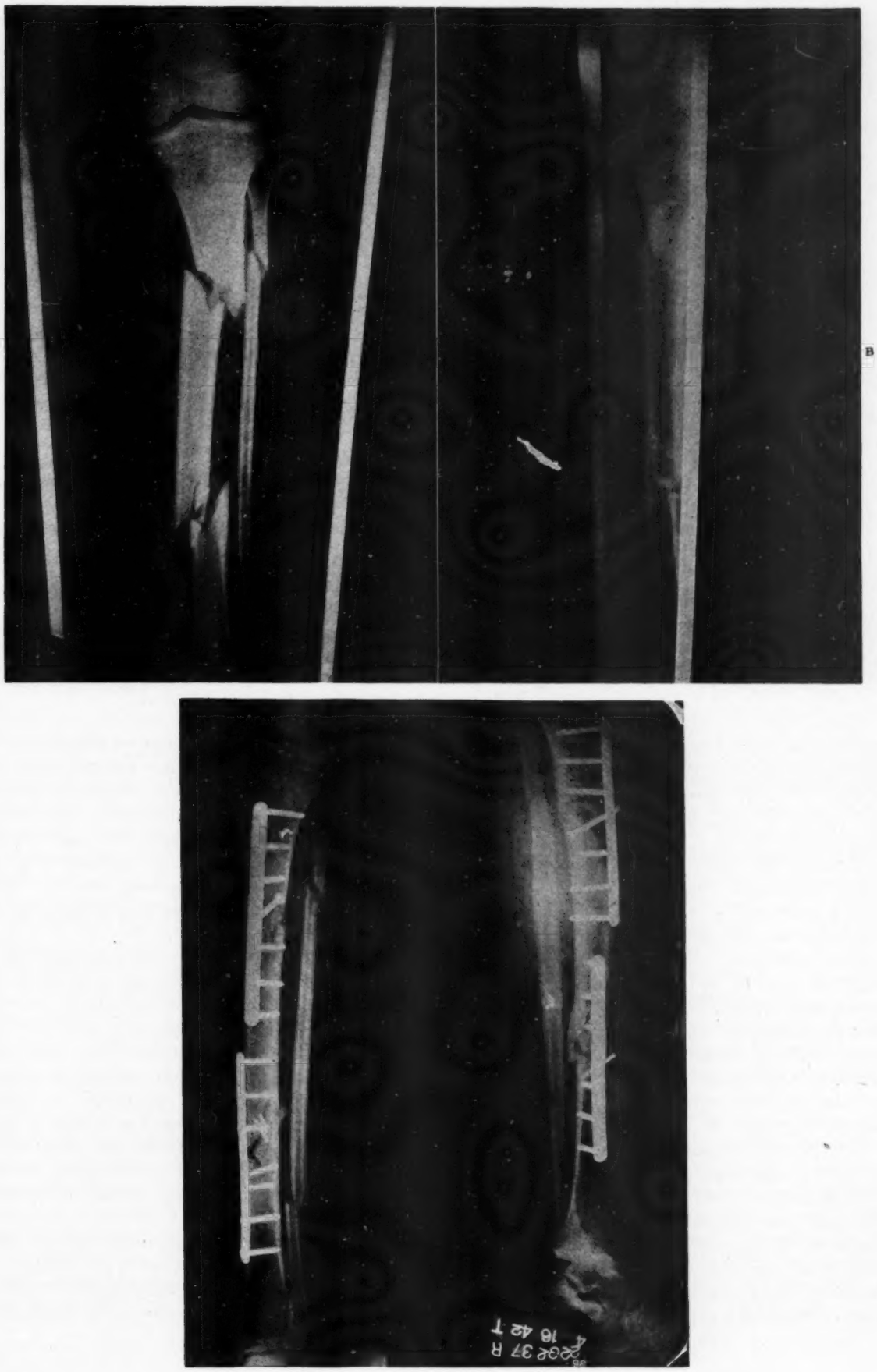


FIG. 2. A and B, original injury, both fractures compound; C, post-plating.

D

FIG. 2. D, result; all wounds healed with full function.

pound fractures was made for the Sub-Committee on Surgical Infections of the National Research Council and cases were brought from all over the city, hence the larger number treated. (Table 1.)

What is the rationale underlying the use of metal plates and screws for fixation of a compound fracture? If the bone ends are rigidly fixed, further damage to the surrounding soft parts is eliminated. Without rigid fixation any slight motion of the jagged fracture will tear tissue and cause further bleeding which, although minute in amount, may be sufficient to lower the local tissue resistance and provide a suitable medium for bacterial growth. This is not theory. The writer has seen infected compound fractures in which the systemic reaction and the drainage dropped to a minimum as soon as the slight amount of movement at the fracture site was eliminated by a plate. In one such case the patient, who had been running a septic temperature and had no appetite because of pain, announced as soon as he had recovered from the anesthesia "the pain has gone—when can I eat?" His subsequent course was entirely uneventful except for the pre-existing and easily controlled local osteomyelitis.

Rigid internal fixation also reduces the necessity of worrying about subsequent deformity. (Fig. 1.) Normal length and axes are maintained without the need for readjustment of apparatus or plaster. There have been no cases of non-union in this series in which the fixation was rigid.

Is the method safe? That is the first question to be answered in evaluating a method of treatment. During the period under review there were no deaths in any way attributable to the use of internal fixation. There was one case of spreading infection necessitating amputation. This case will be discussed in detail later. Therewere minor disasters (Table 1) like broken plates and refractures but none that jeopardized life or limb. It is justifiable, therefore, to consider the method worthy of further analysis.

One of the principal arguments against the use of internal fixation is that it introduces or promotes infection. There are enough recorded cases of infection following plating to make this

no idle criticism. But the metal, if properly sterilized, does not in itself introduce bacteria nor does it provide a medium for their growth. If, however, it is improperly applied so that motion occurs and erosion of bone around the screws takes place, bacteria will multiply in the areas of necrosis so formed. The result is at best a low grade localized osteomyelitis, at worst a spreading infection. But the fault lies not with the metal but with the surgeon. It took us a long time to learn that an adequate length of plate and one or more transfixion screws to stop torsion strain were necessary and the two non-unions were a result of our ignorance. Transfixion screws were not used in our series until late in 1938. The amount of metal used, if rigidly applied with even distribution of strain upon the screws, does not increase nor predispose to infection. (Fig. 2.)

TABLE 1

TOTAL COMPOUND FRACTURES—FEMUR AND TIBIA—65
1932–41—30 Deaths—4 Children not included—6
1942—35 Deaths—3 Children not included—2
1932–41 Cases analysed—20
Internal fixation—16
1942 Cases analysed—30
Internal fixation—21
Pin fixation—9

Disasters	1932–41		1942	
	Internal Fixation	None	Internal Fixation	None
Amputations	1	1	1	1
Non-union	2	0	0	0
Broken plates	2	0	0	0
Refractures	2	0	2	0
Sequestrectomy	5	1	6	2
	1932–41		1942	
Hardware removed	15		15	

Rigidity is, therefore, the first principle underlying the use of internal fixation in compound fractures. Plates of adequate length, screws through both cortices placed at right angles to the plate and inserted through drill holes of the correct diameter, and transfixion screws across the fracture line, all are essential features of fixation. If there is loss of bone substance or marked comminution, other methods of treatment of the fracture should be seriously considered.

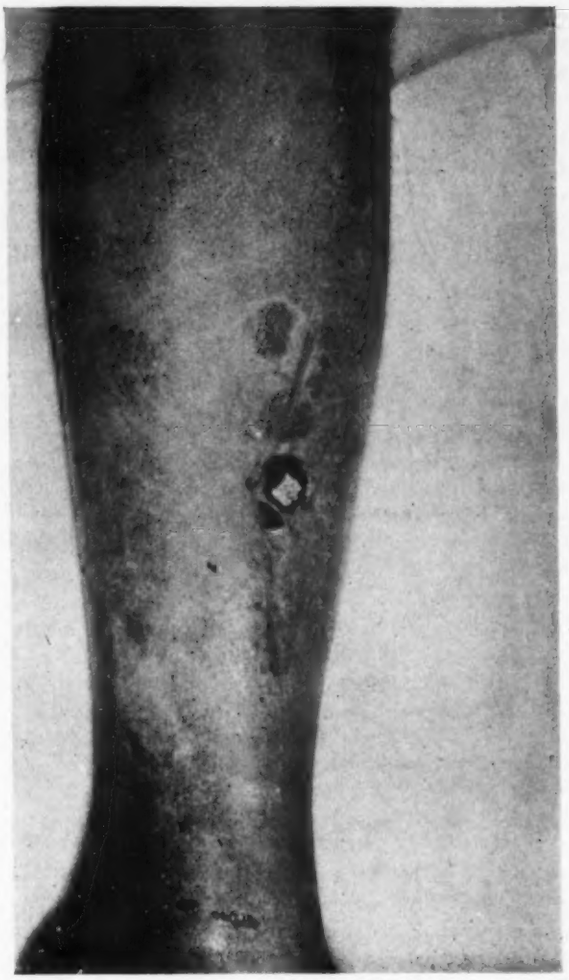


FIG. 3. Compound wound healed except for small area showing exposed plate; no infection.

If rigidity has been obtained, the need for external splinting has been reduced to a minimum and maintenance of function of the adjacent joints can be accomplished with the concomittant improvement of circulation and muscle action. Wound healing in these cases is much more rapid than if circulatory stasis and edema persist.

The initial treatment of the compound wound in all the cases analysed was essentially the same. Surgical débridement and copious lavage with water or saline was done in each case. Separate instruments were used for the plating and gloves and gowns were changed. From 1932 through 1941 all wounds were left open with sutures placed but not tied. Most of them were packed with vaseline gauze. The

sutures were tied, usually without anesthetic, in from four to ten days, in no case completely closing the skin edges. Healing was uniformly slow, pinch grafts being necessary in a majority of the cases. In the 1942 series, because of the nature of the study, some of the wounds were closed initially. The results are tabulated in Table II. Where rigid fixation was not obtained and where plaster encasement were required, the healing was delayed.

TABLE II
WOUND HEALING—1942
INITIAL CLOSURE

Internal Fixation

1 (O) healed at 21 days
1 (S) healed at 21 days
1 (S) healed at 25 days
1 (O) healed at 9 days, broke down 7 weeks
1 (O) healed at 8½ months
1 (S) healed at 9 months
1 (S) not healed 3 years

Pins

1 (S) healed 2½ months
1 (S) healed 3 months
1 (S) healed 3½ months
1 (S) healed 4 months
1 (S) healed 4½ months

O = No chemotherapy
S = Sulfanilamide in wound and orally

In a number of cases the wounds, though not clinically infected, did not heal completely until the hardware was removed. (Fig. 3.) Because of the position of the compound wound plates and screws were placed on the bone surface presenting to avoid excess exposure. Such plates are used as temporary splints and removal after the fracture has united is not considered a failure of the method.

Chemotherapy in the light of present experience is not discussed because it was not used. Undoubtedly penicillin and other antibiotics make the surgeon sleep better at night but replace neither careful surgery nor mechanical principles.

The case mentioned earlier in which amputation was necessary had an undébrided and undrained area of damaged tissue in the posterior compartment of the leg and had the fascial layers sutured over the plate. Five days later the wound was widely opened and the necrotic muscle excised. Gas-forming organisms were found in the excised tissues. In spite of wide excision the mixed infection was not controlled and amputation was performed six weeks later. This result was due to inadequate débridement and tight closure. The presence of the metal did not jeopardize the management of the infection but actually made it easier.

The follow-up results of five years or more are shown in Table III.

In order to include some of the experience gained in the war the writer (thanks to the courtesy of colleagues in Great Britain) has been able to obtain late results on fourteen war injuries of femur and tibia that had some form of internal fixation. The operations were performed at intervals varying from three days to six weeks after wounding, usually through a separate incision. All wounds were left open for five days then sutured under an anesthetic. There were no deaths, no amputations, no spreading infections and no non-unions. Of the nine compound fractured femurs four were still in the army in 1947. The other five were employed at full time jobs but two had limited knee motion. These two had been in plaster spicas for some months. All wounds were solidly healed. The five men with compound fractures of the tibia were all employed but two had limitation of knee motion. Four of the fourteen had received systemic penicillin but almost all had had calcium penicillin sulfathiazole powder in the wounds.

TABLE III
RESULTS
1932–1942

	Internal Fixation	None
4-4-4	10	1
3-4-4	9	1
4-3-4	2	1
3-3-4	9	4
3-3-3	..	1
Death due to other causes	2	
Amputations	2	1
Lost	2	4

In recording follow-up figures the findings are listed according to anatomic, functional and economic results: 4 = 100%, 3 = 75 to 99%.

Although these figures are too small to warrant sweeping generalizations, after analysis of the cases used for this paper the writer is of the firm conviction that certain compound fractures of the lower extremity should be plated. The criteria essential for satisfactory results are correct surgical treatment of the

wound which should include no initial skin closure but adequate suture under anesthetic at five days and rigid mechanical fixation of the fracture.

In conclusion, the impressions gathered over the past eighteen years have been strengthened by this study. Compound fractures of the shafts of femur and tibia, suitably selected and properly plated, are best treated by internal fixation.

DISCUSSION

Henry C. Marble (Boston, Mass.): I want to say that I consider this a privilege and an honor. This is the first paper that has ever been presented to this Society by a lady member and this is the first lady member.

I read her paper and I was reminded then only of the first time that this matter was proposed in my surgical experience. Dr. O'Neill Sherman, of Pittsburgh, gave a paper not unlike this before a part of the American College of Surgeons, and I believe it was in Montreal. Dr. Sherman finished his paper and the audience arose almost to a man and what happened to Dr. Sherman was very much like what happened to the merchant of Venice. They tore his raiment, they spit on his garline, and when he was through, with one or two notable exceptions, poor Dr. Sherman's paper was torn to bits.

Two or three decades have brought about a wondrous change, and now Dr. Stimson comes and reiterates what Dr. Sherman then said and we sit here quietly and blandly in our seats and agree.

Of course, one cannot but agree with what she has said. There are several factors which we have learned in these years. The first factor is how to do a proper, careful, accurate débridement. I might add that Dr. Stimson did not tell you but she probably does it—namely, that portions of the débrided tissue may to advantage be put into test tubes and subjected to the bacteriologist's wiles to see if they are benign or if they are malignant.

It is a great comfort to have the bacteriologist tell you the day after you have sewn up such a fracture that as far as he can see, there are no clostridial organisms and not too many streptococci in the wound, although parenthetically I have had gas-forming organisms in wounds in which there was no clincial evidence whatsoever. However, that is good for peace of mind.

We have also added to our armamentarium certain other drugs which Dr. Stimson says make her sleep better. Peace of mind for a surgeon is a grand thing. Off the record, sulfa drugs do not give me peace of mind, and giving all of my patients penicillin does not help my peace of mind either. I firmly believe that a careful, thorough, painstaking débridement, carefully controlled by bacteriologic test, will give you all the peace of mind you need. If the bacteriologist shows you that there are organisms in there that require attention, then we have the sulfa drugs and we also have penicillin. Added to that, we then must fix the fracture, as she has told you, and we must close the wound.

I want to add that in closing the tibial wounds, which I think are difficult, the old expedient, which Dr. Fred Cotton taught me, of making lateral incisions far to the side of the leg so that the tibial wound over the plate can be completely closed, is useful and helpful and these lateral incisions can then or later be closed by skin graft.

Oscar P. Hampton, Jr. (St. Louis, Mo.): It is a privilege to discuss Dr. Stimson's paper. It was my privilege to see some of her excellent work in Italy. When the American Army turned down Major Barbara Stimson, with all of her knowledge of bone and joint surgery, it was a British gain, because she certainly contributed a great deal to the management of soldiers of the British Army who were bone and joint casualties.

I might say that, without disrespect to our British allies, she certainly rocked them on their heels in the early days because she wanted to put metal on bone in compound fractures. That was heresy. When she came to North Africa but after she had moved to Italy and carried on there, others of the British Medical Corps were doing it, too. She carried her point and her concepts were well received when she was through.

Of course, the use of hardware in compound fractures really requires consideration in two phases. Relatively speaking, its use in fractures soon after injury has been accepted. I say "relatively speaking." There are still some who do not or would not use it, but there are many others who always or frequently do.

I would like to point out that in her use of the metal in compound battle fractures, Dr. Stimson was placing this metal in compound wounds several days, perhaps several weeks, after wounding. I know that she thought the ideal time was five days after wounding, but the majority of the internal fixation were done from five to ten days after wounding. I believe we can draw an analogy to comparable fractures seen in civilian life. We receive them from distant places or we may have them under our care from the beginning. Unreduced fractures with open wounds, five to ten days after injury—that is the problem.

Now, Dr. Stimson stated it frankly, that the problem of the use of metal presents itself in this way: Does it produce infection? I would like to present again for your consideration the concept that wound sepsis results from the septic decomposition of dead tissue, including blood clot in dead space. Particularly is this true in the presence an effective antibacterial agent to protect living

tissue from invasive infection of organisms recognized as still present in the retained devitalized tissue and in the open wound; so that if a wound can be rid of devitalized tissue by a meticulous débridement, of which Dr. Marble spoke, and the surgery is good enough to put on the metal without creating additional devitalized tissue and to eliminate residual dead space, how is the metal going to predispose to sepsis. It does not if this concept is accepted.

I would like to speak briefly about the use of metal in septic wounds. Often, the rigid internal fixation of a fracture may be an important factor in overcoming a septic compound fracture.

A septic compound fracture presents two problems: one, control of sepsis and wound healing; the other, maintenance of reduction of the fracture projected toward healing in as near an anatomic position as possible.

Now, if one accepts the concept which I outlined, the use of metal is not going to prolong that sepsis and, as Dr. Stimson said, by holding the fragments still, continuing trauma and subsequent devitalized tissue is minimized. I also would like to point out that dead space about the unreduced fracture is eliminated.

Barbara B. Stimson (closing): I want to thank the discussers for their courteous handling of the paper.

I agree entirely with Dr. Marble that skin closure is essential as soon as it is safe. We found that in five days, most of the very bad wounds could be closed with not much tension. We have used the lateral releasing incisions with a great deal of interest and help, because I agree with him that it is essential to cover the tibia, if possible.

Of course, I agree with Dr. Hampton. We have seen a number of septic compound fractures that progressed very satisfactorily with the use of internal fixation. We have plated them at a month and a month and a half, in the presence of pus, and the bones unite and the sepsis is controlled.

SURPLUS PARTS OF THE SKELETON*

A RECOMMENDATION FOR THE EXCISION OF CERTAIN PORTIONS AS A MEANS OF SHORTENING THE PERIOD OF DISABILITY FOLLOWING TRAUMA

FRASER B. GURD, M.D.

Montreal, Canada

THE author wishes to present the thesis that certain parts of the skeleton, including both bone and cartilage, are unnecessary for the reasonably normal functioning of that part of the body to which they belong; I wish, however, to make it clear that the recommendations for bone sacrifice which are made herewith are to be applied only in the presence of those lesions which experience has proved are difficult to treat by more conservative measures. I am particularly anxious not to be misunderstood in the matter since, although I believe that certain fractures are better treated by resection of parts, I am not in favor of removal of bone unless there is an indication therefor.

As proof, I believe, that there has been for many years a general agreement on the part of surgeons that certain portions of the skeleton, if cartilage be included in this classification, are better removed than attempts made to promote healing; the menisci in the knee joint may be used as examples. With reference to these fibrocartilages, more especially the medial, it has long been proved, I believe, that they are surplus in that they are not necessary to the proper functioning of the joint, and that when damaged it is advisable to excise the cartilage which is the site of injury. Furthermore, it may be expected that slight or no disability will result from such removal. There has been general agreement, also, that the coccyx in the human being is not very useful and that its resection may be indicated when, as the result of fracture and malunion, disability is suffered by the patient.

In this contribution it is suggested that there are other individual parts of the skeleton that are of minimal importance, and that not only may time be saved in return of the individual to duty but that in many instances the end result of excision may be better than that which follows the employment of complicated procedures, many of which are difficult to perform and which are of necessity followed by long periods of disability in order that healing may take place. It is also true, I believe, that in many instances delay in removal of damaged parts may result in secondary changes which are irreversible.

It is not the intention of the author to claim priority for any of the procedures discussed or recommended. It would appear to be true, however, that the philosophy which underlies the thesis, which is suggested herewith, has not previously been presented. Although a few references have been included I believe that no useful purpose would be served by an attempt to prepare a bibliography or to trace the originators of any individual procedure. Since in fact the growth of surgical art has been gradual and all writers have either purposefully or unknowingly taken advantage of the contributions made by their predecessors, I make no apology for failure to give adequate credit.

Among those parts of the skeleton which are, in the author's experience and opinion, relatively unnecessary, the following are listed for consideration. As the matter is discussed in the following pages, it will be noted that the indications for excision are more positive in some instances than in others: (1) clavicle, (2) acromion process, (3) head of the humerus, (4) lateral condyle of humerus—capitellum, (5) median epicondyle of humerus, (6) olecranon, (7) head of the radius, (8) distal fifth of the ulna, (9) carpal scaphoid, (10) carpal semilunar, (11) menisci of the knee joint, (12) head of the fibula, (13) patella, (14) rib cartilages, (15) ribs and (16) coccyx.

Clavicle. In 1941, the author published an article upon the subject of complete dislocation of the outer end of the clavicle. In this article the recommendation was made, that in cases of complete dissociation of the lateral end of the clavicle from the acromion, a lesion which is accompanied by rupture of all or nearly all the ligaments taking part in the acromioclavicular

* From The Montreal General Hospital, McGill University, Montreal.

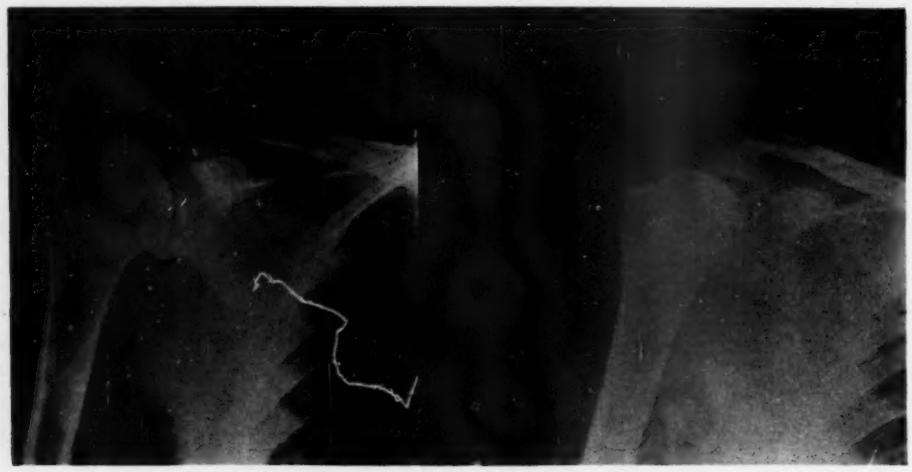


FIG. 1A

FIG. 1B FIG. 1C FIG. 1D

joint, the treatment of choice consists in the resection of the lateral third of the clavicle. A similar recommendation is made with reference to fractures of the outer third of the bone, a lesion which may be considered a variant of the former. Although dislocation of the sternoclavicular joint is not followed by any serious loss of function, the disfigurement may be important. It is recommended, therefore, in the treatment of this lesion that the medial third, or half, of the clavicle be excised.

In the contribution referred to attention was drawn to the fact that the clavicle may be removed *in toto* without any disability and with but minimal deformity arising therefrom; also, that the removal of the outer third of the clavicle in the treatment of the lesion referred to results in a strong shoulder without any disability, and that the total period of loss of time which follows operation is short. Since the clavicle is practically useless to the human frame, and since occasional though unusual cases of non-union are seen, resection of the whole bone is, in the author's opinion, preferable to the exhibition of procedures designed to promote union in such cases. As Copland has suggested, resection of the whole clavicle may be indicated in a rare case of fracture of the middle third of the bone with extensive comminution.

Since the publication of the above article several contributions have appeared in the literature which support the author's contention. Among these are those of Mumford, Copland and Elkin.

Acromion Process. Fracture of the acromion

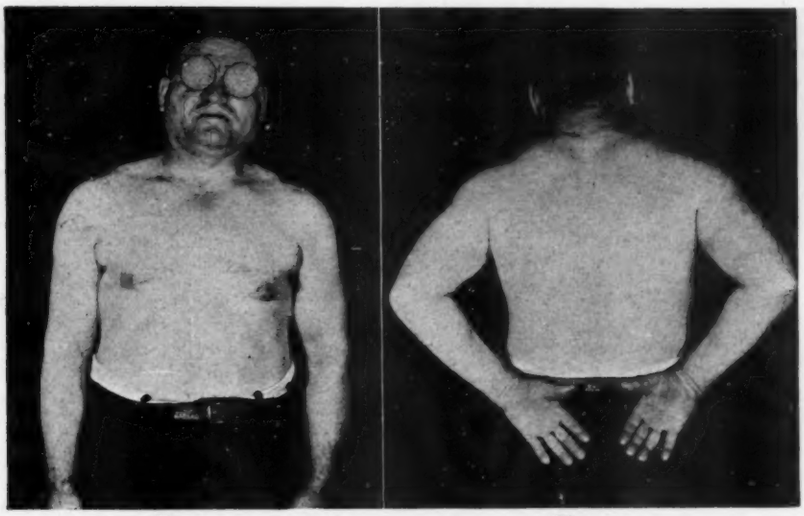


FIG. 1E FIG. 1F

FIG. 1G

FIG. 1. A to G, Case C. N., show acromion process completely removed together with (accidently) tip of clavicle. Seven photographs indicate site of incision and show that there is minimal loss of function and atrophy.

is an unusual injury nor does it, as a rule, require any considerable length of time for union to take place. Nevertheless, although the procedure is not urged unduly, the suggestion is brought forward that in certain cases, at least, of fracture of the acromion process excision of the distal fragment is followed by no demonstrable loss of function, and that the length of time required before return to full duty may be shortened by the employment of such a procedure.

In a limited number of cases of subacromial bursitis (frozen shoulder) accompanied by extensive involvement of the bursa more room is made available to carry out whatever interference may be necessary if the so-called sabre cut over the top of the shoulder be used. If this incision be employed, that part of the process which is separated from its base should be resected. Not only does such a procedure avoid delay of healing, since more space is made available for the affected bursa, but more complete and more prompt return of function may be expected.

In the majority of cases demonstrating lesions of the cuff or of calcium deposition in the floor of the bursa such a radical incision is not required; in the selected case, however, such as that indicated above, the sabre cut is valuable.

If the acromion process is resected, it should be done in such a way that sufficient tendinous and periosteal tissue is conserved to make it possible to suture the muscle bundles to one another. If this be done, the function of the shoulder joint is but little disturbed.

CASE 1. No. 8772-46. C. N., fifty-eight years of age, a stoker, was first seen on December 18, 1946. He had been totally disabled on account of extreme pain and loss of function of the right shoulder for a period of three months during which time physiotherapy, including x-ray therapy, had been employed. X-ray examination showed the presence of

A

FIG. 2. A, McKim's case. Displaced head of the humerus is barely visible several inches away from the glenoid.

a radio opaque substance in the subacromial bursa, though not in the usual site.

Operation was performed on December 20th. An incision was carried over the top of the shoulder. The lateral portion of the trapezius and the deltoid muscle was separated from the acromion process in such a way that a small portion of periosteum was left attached to the muscles. The acromion process and, accidentally, a small portion of the distal extremity of the clavicle was resected. Bethune shears were employed for this purpose. The roof of the bursa was thus completely exposed. It was found to be greatly thickened and, as suspected, the calcium deposition was in the roof. The whole of the roof of the bursa was resected. The bursa itself was found to be almost completely obliterated by adhesions between the superficial and deep portions. All tendons attached to the cuff were found to be intact and no interference in the floor of the bursa was carried out. The wound was closed with fine black silk sutures and the patient returned to bed with the wrist attached to the crossbar and the head of the bed raised. This position was maintained for five days, after which he was allowed out of bed and the wrist reattached to the head of the bed overnight for an additional five days.

The accompanying photographs show that four months after operation movements were substantially complete in all directions, were free from pain and that little or no muscle atrophy had occurred. (Fig. 1.)

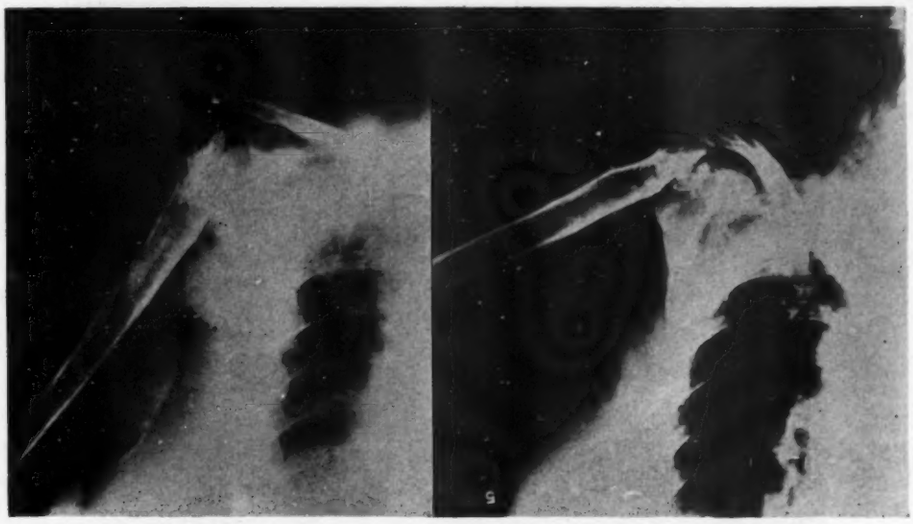
Head of the Humerus. In elderly people fractures through the anatomic neck of the humerus are rather common injuries. In such cases there is usually complete or almost complete separation of the proximal fragment from its blood supply. Furthermore, there is often marked displacement of the head. In the author's experience no matter what form of treatment is carried out in this older group of persons, usually women, it is more or less impossible to obtain a perfect result I believe, however, that as a rule the most satisfactory end result is obtained by early removal of the head.

Although the case referred to herewith, and for which I am indebted to Dr. L. H. McKim, is exceptional in so far as the displacement of the head was concerned, the fact that a reasonably good shoulder followed resection is at least suggestive:

CASE II. Mrs. A. J. S., sixty-five years of age, fell down the stairs on April 24, 1936. X-ray showed fracture of the surgical neck of the left humerus with marked comminution and very marked displacement of the head. At operation the head was found in the substance of the left breast. The displacement had apparently taken place by the head following down the posterior surface and the lower edge of the pectoralis major muscle. The arm was placed in a Thomas splint with abduction and elevation of the arm. This position was maintained for about one week after which the patient was allowed to get up.

The patient was examined one year later; she had, in the meantime, been doing all her housework and had an excellent functional arm. At that time the grip of the left hand was one-half that of the right. She was seen again in 1940 four years after the injury. Her statement at that time was that she could do everything except put her hand behind her head. She was reexamined on May 21, 1947, eleven years after injury. The patient is now seventy-six years of age. The movements at the shoulder are good with the exception that she cannot elevate the humerus to more than 90 degrees as compared with 140 degrees on the right side. The grip of the left hand is now two-thirds that of the right. (Fig. 2.)

When operating upon the more usual case the author wishes to caution the surgeon who is not very familiar with the anatomy in the inferior part of the shoulder joint region. This caution applies particularly to the risk of damage to the circumflex nerve as it descends through the quadrilateral space and to the main trunk of the musculospiral as it curves around the scapular head of the triceps. It is wise, I believe, to cut through the tendinous attachment of at least the lower part of the pectoralis major muscle to the humerus and so obtain a clear view of the axillary structures and of the



B C

FIG. 2. B and C, x-rays illustrate movement at the shoulder four years after injury.

lower part of the capsule. The head will commonly be found protruding from a rent in the capsule. This explains in large measure the difficulty that there is in many cases in closed replacement. As indicated above, it is the musculospiral nerve which runs the greatest risk of damage. This nerve should, therefore, be clearly identified and protected during the operative manipulations required for removal of the head of the bone.

Lateral Condyle of Humerus—Capitellum. Fracture of the lateral condyle of the humerus to which is attached the capitellum (Fig. 3), that is to say that portion of the lower end of the humerus which is in contact with the head of the radius, although it is not a very common injury in adults, does nevertheless occur in an occasional case. Reduction of the displaced bone fragment and maintenance of position is somewhat difficult, consequently, in many clinics it has been the practice to carry out open reduction and to fix the fragment in position by means of screws or nails.

Since as a matter of fact the entire articulation of the forearm with the humerus is through the ulna and the trochlear surface of the humerus, it is evident, I believe, that it is not necessary that the upper end of the radius come in contact with any bony surface. It is recommended, therefore, that in the event of fracture of the lateral condyle of the humerus in the adult, the separated bone fragment be removed. If this be done, there is no necessity for fixation during the period of repair, and function may be started almost immediately.

It should be made clear that this procedure is not recommended in children. Resection of the lateral condyle has been carried out in a sufficient number of cases in the adult to prove that time is saved, a simple operative technic is employed and no appreciable deformity nor loss of function results.

A curved incision, convexity forward, over the anterolateral border of the arm is used to expose the loose fragment; a partially subperiosteal resection of the bone is accomplished with as little damage to the tendinous attachments of the extensors as possible. Preliminary identification of the musculospiral nerve and its branches is recommended.

Humerus—Medial Epicondyle. Since in a fairly large proportion of cases of separation of the median epicondyle of the humerus the detached bone fragment cannot be replaced without operation, and since it is likely to interfere with joint function and jeopardize the ulnar nerve, there is, I believe, a general agreement that in such cases it is wise to remove the fragment.

Olecranon. In general, there is every reason for repair of the usual transverse fracture of the olecranon; there are, however, cases of direct injury with fragmentation in which excision of bone fragments would appear to be indicated. When this is done, very careful suture of the triceps fascia is imperative. As stated in the opening paragraph of this contribution, the procedure is adopted as the lesser of two evils and is one which is usually forced upon the surgeon by the circumstances of the case.

A

B

FIG. 3. A and B, x-ray photographs illustrating fracture of the lateral condyle including capitellum treated by resection without loss of function.

Head of the Radius. Fractures of the head of the radius (Fig. 4) vary much in severity and consequently the treatment thereof must differ depending upon the nature of the lesion. In children, that is to say before the epiphysis has become attached to the metaphysis, removal of the head of the bone should not be attempted. Fortunately, it is usually possible to replace the displaced fragment by open reduction without the necessity of employing any foreign material whatever.

In the adult, in those cases in which cracks of the bone without gross displacement of any sort are present, it is probably unnecessary to carry out any active form of treatment but to advise the patient to exercise the limb so long as pain is not produced. In more important injuries but without gross displacement, and in the majority of cases of fracture through the neck, it is recommended that the limb be fixed with the elbow at a right angle and the hand and forearm in full supination. As a rule, three weeks' fixation in this way is sufficient, at the end of which time plaster should be removed and the condition of the head of the radius determined by x-ray examination.

In those cases in which the fracture is more impressive, whether this be as the result of gross comminution or in consequence of the separation of an individual fragment from the head, resection of the head and neck of the radius is strongly recommended.* A long and somewhat extensive experience in removal of the head of the radius has made it clear that this part of the anatomy is surplus; I would urge, however, that when arthrotomy of the elbow joint in consequence of fracture of the head of the radius is carried out, it is unwise to simply remove a loose fragment or fragments, nor will the result be satisfactory if the neck of the bone is not also removed. The upper part of the radius, therefore, should be divided close to the bicipital tubercle without, however, encroaching upon the latter.

Dislocation of the head of the radius in the adult is usually associated with fracture at about the junction of the middle and upper third of the ulna—Monteggia fracture. In such cases it is recommended that union of the ulna be permitted to take place before the displaced head of the radius is interferred with. It is not within the scope of this contribution to discuss the treatment of fractures of the ulna; as is well known, however, this is not always an easy matter. Our experience has been that the insertion of a Kirschner wire through the olecranon and so through the medullary cavity of the bone is the most effective form of treatment.

Arthrotomy of the elbow joint for the purpose of resection of the upper end of the radius has been recommended through different incisions. The author would like to recommend for this purpose an incision on the anterolateral border of the joint. A curved incision, convexity forward, on the anterolateral border of the elbow joint about 7 cm. in length, is made through the skin and superficial fascia. This is carried down to the deep fascia which is incised slightly more laterally; the trunk of the musculospiral (radial) nerve in the lower part of the arm is then identified and gently retracted together with its branches. If this be done, damage, to this important structure is avoided.

The capsule of the joint slightly anterior to and below the lateral epicondyle is thus somewhat widely exposed. It is entered by plunging blunt-pointed scissors of the Mayo type into the joint. The appearance of synovial fluid in the wound is proof that the joint has been entered. The capsule is torn open by spreading the scissors and an adequate arthrotomy thus established. The capitellum is identified and the fractured head of the radius clearly exposed. Sufficient room is made available so that the whole of the neck of the bone is seen. It is wise, I believe, to remove a cuff of periosteum distal to the line of division of the bone so that reformation of spicules will be less likely to occur. I have been accustomed to divide the neck close to the tubercle of the biceps, using for this purpose rib shears of the Bethune type; as a rule, two bites are required to divide the bone completely which is then carefully smoothed off, using either the same instrument or a sharp rongeur. Usually few or no ligatures are required. The synovia and capsule are sutured, as best may be, either with very fine black silk or very fine chromic catgut.

Ulna—Distal Extremity. Whereas the ulna forms the entire articulation of the forearm with the humerus, it is equally true that the radius alone is required in order to articulate with the carpus, and so the hand. In other words, whereas the head of the radius is an unnecessary part of the anatomy, the distal fifth of the ulna is equally unnecessary. Dr. William Darrach, I believe, first (1913) recommended removal of the distal end of the ulna in the treatment of unreduced cases of Colles' fracture with deformity and shortening of the radius. Following the first stage of the War, that is from the autumn of 1918 until the summer of 1925, during which time the author was in charge of the Surgical Service at Ste. Annes Military Hospital, many cases of non-union of fracture of the lower end of the ulna were admitted. It was found that by removal of the bone, or by resection of a portion thereof, practically perfect function was obtained. (Fig. 5.)

Since 1925, in civilian practice, the number of cases which have been seen of either non-union in the lower fifth of the ulna or in which shortening of the radius has been followed by disability consequent upon the relatively long ulna has not been large. A sufficient number of patients have, however, been operated upon to confirm the opinion that the ultimate fifth of the ulna is surplus. It is recommended, therefore, that in the event of non-union of the lower end of the ulna either the distal extremity should be removed or a segment of bone resected so that the bone ends will not come in

* Needless to say that if a loose fragment of the capitellum be found in the joint, it should be removed.

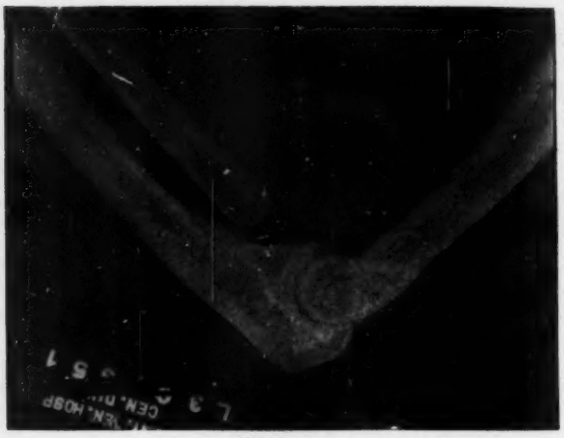


Fig. 4A

contact with one another. In the treatment of valgus deformity at the wrist joint, whether due to an unreduced Colles' fracture or premature fusion of the radial epiphysis, excision of the lower ulna to above the inferior radio-ulnar articulation should be carried out.

Scaphoid (Navicular). For many years there has been much discussion regarding the advisability, or otherwise, of removing the fractured scaphoid from the carpus. The author does not wish to suggest that its removal is the procedure of choice. Although I believe that it is true that twenty years ago fracture of this bone frequently resulted in non-union, such is not the case today. In this connection I quote, at some length, from the contribution on the subject by L. H. McKim who says, in part, as follows. As the result of the treatment of 125 fractures among soldiers and air men, he states, "All cases were treated by plaster fixation. The average period of fixation for acute cases was 9 or 10 weeks. Union was frequently good after 6 weeks. Some old cases were fixed for 8 months. Position of fixation is very important. Joints do not tend to become stiff when fixed in a functional position.

"The position of maximum function of the wrist is best demonstrated by the following procedure:

1. Clench the fist and note the following:
   a. Degree of dorsiflexion of the wrist.
   b. Degree of ulnar deviation of the hand.
   c. Position of opposition of the thumb to the fingers.
2. Extend the phalanges of the thumb and note that: The metacarpal bone of the thumb is now in direct line with the shaft of the radius.
3. Now extend the fingers at the metacarpophalangeal joints.
4. Apply the plaster case in this position with careful observance of the above points. The terminal phalanx of the thumb and the metacarpophalangeal joints of all the fingers must be free"

None of the fractures in McKim's series failed to unite. He further states that he has never seen non-union in a case of fracture of the seaphoid that has been adequately treated from the time of injury.

Despite improvement in the treatment of fracture of the scaphoid by a better understanding of both the position of the hand during fixation and the absolute necessity for preventing all movement of the carpus during the period of healing, there still remain a certain number of cases of non-union. In such cases a very disabling arthritis is very likely to occur if the lesion is not corrected. In such cases, moreover, delay in operative treatment (removal of bone or successful bone graft) results in a very serious disability unless arthrodesis is carried out.

In the foregoing paragraphs the author has, I believe, made clear that he does not recommend removal of the carpal scaphoid in all cases, or even in a large proportion of cases, of fracture; on the other hand, he wishes to present the argument that early removal of both fragments is not followed by any considerable disability. It is, therefore, in my opinion, reasonable to suggest that time is saved, the risk of ultimate seriously disabling arthritis is avoided and, since the function of the wrist joint following removal of the bone is but little interfered with, there is little or no objection to excision, particularly in fractures associated with any considerable displacement.

The operation for removal of the carpal scaphoid is not easy. It is difficult to obtain wide exposure without damage to essential structures; I believe, therefore, that a short outline of the technic, which in the author's experience has proved most satisfactory, is not out of place.

With a sand pillow beneath the ulnar border of the carpus and with the hand in mid-pronation, a curved incision with convexity toward the dorsal surface approximately 8 or 9 cm. in length with its center opposite the styloid of the radius is made. This incision is carried down through the thin skin, the small amount of subcutaneous fatty tissue and the flap turned back-

B

C

FIG. 4. A to C. x-ray and photographs illustrating appearance of upper end of the radius and almost complete function of the elbow joint and rotary movements fourteen years after resection. Note especially the site at which, in the author's opinion, division of the bone should be made.

FIG. 5A

ward. This exposes the fascia on which is seen the branch of the radial nerve and beneath which are the tendons to the thumb. The small radial nerve is displaced along with the extensor tendons to the fingers and to the wrist, as well as the long extensor to the thumb, and the tendons on the radial border of the snuff-box displaced toward the radial side. If this is done gently, it is possible to uncover a substantial portion of the capsule of the radiocarpal joint. The proximity of the radial artery must, of course, be borne in mind. Through the exposed capsule is plunged the points of scissors of the Mayo type. When the synovial fluid appears and it is clear that the joint has been opened, the points of the scissors are spread sufficiently to tear an opening into the joint to permit reasonably adequate exploration.

The author is of the opinion that it is advisable to remove both fragments when a decision has been arrived at to remove either one. Careful exploration of the joint should be made with a view to discovering the fracture line in the bone. If this is done, one can be certain that the bone which is to be removed is, in fact, the scaphoid. If the fracture line is not identified, it is difficult to be sure that the bone which is grasped is the one that has been damaged.*

*That it is difficult to differentiate between the bones in the carpus is illustrated by the recommendation to place a skin clip on the bone before removal and prove its nature by x-ray examination (Campbell).

The late Dr. Frederick J. Tees recommended the use of dental forceps as a means of holding and fixing the bones in the carpus while their attachment is being divided. The use of such instruments is to be recommended.

Experience in a number of cases in which the scaphoid had been removed through the incision referred to and a dislocated semilunar removed at the same time through an anterior incision, suggests that it is perhaps wise to remove both semilunar and the scaphoid when indications are present for the removal of the latter. In this event both bones are, of course, removed through the posterolateral incision. Not infrequently damage to the lower end of the radius complicates fracture of the scaphoid or dislocation of the semilunar bone. In such cases, I believe, early removal of one or both bones is more imperative. (Fig. 6.)

Although perhaps not quite apropos with regard to the present contribution, the fact that not infrequently fractures of the carpal scaphoid are complicated by injury to the lower end of the radius must always be borne in mind. In such cases, the possibility of obtaining a thoroughly good result from treatment is problematical; in general, however, I believe that this complication is an added reason for operative removal of the fractured scaphoid.

Dislocation of the Semilunar (Lunate). Since the author's opinions with reference to complete dislocation of the semilunar bone are crystallized, an extensive discussion of this subject will not be included. I believe that it is inadvisable to attempt closed reduction of the dislocated semilunar since, on the one hand, considerable damage may result in attempts at reduction and, on the other hand, the risk of aseptic necrosis is great. If the carpal semilunar be removed soon after injury, the disability which ensues is minimal and the patient is able to return to work after a shorter period of convalescence than if even a successful attempt at reduction has been possible.

Removal of the dislocated bone is a simple procedure. A curved incision on the volar surface of the carpus surrounding the prominence made by the dislocated bone exposes the median nerve and the long flexor tendons. These are gently retracted and, when the bone is grasped, a few snips of the scissors suffices to separate it from its remaining attachments. A ten-day period of fixation in plaster with the wrist and hand in the position of rest should

B C

Fig. 5. A to C, photographs and x-rays, small boy who suffered compound separation of radial epiphysis at twelve years of age. Four years later marked valgus deformity treated by resection of distal portion of ulna, x-ray appearance of wrist twelve years later at which time only slight disability existed.

be followed by a similar period of active movement.

Head of the Fibula. Although with the change in the level of front bumpers on automobiles fractures of the head of the fibula have become less frequent, such injuries do, however, occasionally occur. Without laboring the thesis the author wishes to recommend that in such cases a subperiosteal resection of the head of the bone is easily carried out, is followed by no disability and the length of time required before the patient can return to full duty is determined only by the period required for healing of the soft tissues. That the fibula, except for its lower fifth or quarter, is not very valuable is proved by the willingness exhibited by surgeons to use this bone for bone grafting purposes.

Patella. Since resection of the patella has been discussed in the literature at such length since Brooke's original article, I shall not discuss this subject in any detail here. Although I am of the opinion that, if possible, the patella should be conserved at least in cases of transverse fracture, frequent experience on the part of many surgeons has proved that this bone is not absolutely necessary in order that function of the lower extremity may be adequate. In the event, therefore, of comminution which renders accurate replacement of fragments difficult or impossible, it may be advisable to remove the bone and to re-establish the extensor mechanism of the knee joint from the soft tissues.

Costal Cartilages. It is of interest that there is little reference in the literature of trauma to fracture of the lower rib cartilages. This rather common injury appears to have been overlooked by most authors. In the recently published work by Bancroft and Murray on "The Motor-Skeletal System" the article by Harrison L. McLaughlin, entitled "Injuries to Ribs, Costal Cartilages, Sternum and Sternoclavicular Joint," although the title of the chapter includes the "Costal Cartilages," the text as a matter of fact makes no reference to them.

Although contusion of the anterior portion of the lower chest wall is not as a rule a serious matter and disability does not persist for any considerable length of time, when either the cartilages are separated from the rib ends, or from one another, or themselves fractured, an annoying disability is experienced by the victim in that the broken ends are likely to slip over one another with changes of position, this slip being accompanied by a sharp pain.

As is well known, cartilage repairs itself inadequately and slowly; it is, therefore, recommended that in the event of fracture of the rib cartilages below the fourth, or separation from the bone ends, a length of 2 cm. more or less from each end be excised. The operation is, of course, a simple matter, carried out under local anesthesia, and is followed by complete relief and complete healing within a few days.

Removal of a costal cartilage above and including the fourth is to be avoided since a soft

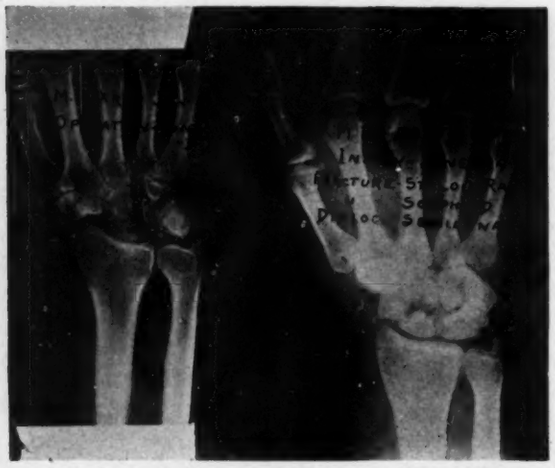


FIG. 6. X-ray photographs of wrist in which dislocation of the semi-lunar, fracture of the scaphoid and of the radial styloid was treated by resection of the two carpal bones. This man recently examined showed slight disability only.

spot is produced which is annoying, on the one hand, and may result in a hernia of the lung in the upper part of the chest and may expose the heart to damage. Since injury to the cartilages above the fifth is practically unknown, the above memorandum is not of much importance to the surgeon interested in trauma.

Ribs. Although rib resection as a sequel to trauma will rarely be indicated, for the sake of completeness in the development of the thesis submitted in this essay certain comments are made herewith. Since hundreds of ribs are removed in all clinics interested in the treatment of pulmonary tuberculosis, and since comparatively little disability usually results from such resection, it may be said that these bones are of no great importance to human physiology. In this connection may I submit the thesis that, although the ribs are of some importance in the respiratory effort, their chief functions in addition to their protective capacity in so far as the thoracic viscera are concerned are the maintenance of the spine in the erect position and as a *point d'appui* for the powerful muscles attached to them.

That one or more ribs may be sacrificed, in whole or in part, in order that thoracotomy for intrathoracic operations may be performed is recognized by all surgeons as a harmless procedure. In cases of scoliosis consequent upon chronic pleural or pulmonary disease correction of the deformity may be accomplished by resection of bone (rib) segments. In cases of chronic pleural disease, whether consequent upon an organized hemothorax or chronic empyema, a scoliosis with convexity away from the affected side is almost inevitable. In the performance of thoracoplasty for pulmonary tuberculosis, a scoliosis with the convexity toward the affected side is certain. If, therefore, in the case of scoliosis consequent upon chronic disease the patient is submitted to rib resection, it is possible to bring about correction of the pre-existing curvature.

In the foregoing pages the author has discussed the problems presented by injury to a selected sixteen parts of the skeleton. It is clear that other parts may, upon occasion, necessitate resection. In this connection perhaps the most important one is the astragalus (talus) regarding which the only comment I would like to make at the present time is that, although astragalectomy may sometimes be an absolute necessity, particularly in cases of compound injuries with consequent contamination or infection, it is advisable, as a rule, to attempt to conserve this bone in the foot.

Among infrequent lesions, those of the sesamoid bones, is either hand or foot, may be damaged and may require removal. In such cases, their removal is not accompanied by any considerable disability. In the uncommon injury or avulsion of the anterior superior spine in young men, it is perhaps true that, if the bone fragment be removed and the tendinous structures attached to it sutured to the pelvic bone, a more rapid return of function is obtained.

In the event of fracture through the neck of the mandible resection of the condyle is a proper procedure; if, however, a pseudarthrosis is induced by adequate movement during the healing period, such operative interference is unnecessary.

Recent work by Dr. John Gerrie and his associates in the treatment of decubitus ulcers over the trochanters of the femora and over the tuberosities of the ischia in paraplegics has been of special interest to me. They have found that more permanent healing of such lesions is obtained if the underlying bone is removed.

The spinous processes and transverse processes of the vertebrae are easily dispensed with; however, resection, on account of disability as the result of injury is not strongly recommended.

In the foregoing pages, to a limited extent, memoranda have been made with regard to

technical procedures. I do not believe that this matter should be further detailed in this contribution; I should like, however, before bringing this essay to a close to make certain observations in this regard.

In so far as possible longitudinal incisions on the extremities should be avoided. For the most part curved incisions are recommended. The value of the curved incision is two-fold: In the first place, because a flap is formed closure of the wound is likely to be obtained with less tension; it is possible, therefore, to employ finer suture material and so interference with the blood supply to the skin and fascial edges is minimized. Secondly, if a flap is formed by the use of the curved incision, the superficial wound is ultimately situated at some distance from that of the bone or joint, as the case may be. Consequently, if even a minimal infection of the surface wound does occur, spread of the infection to the deeper and more important structures is likely avoided.

Although in the performance of certain procedures, as for instance removal of a meniscus from the joint, the use of a tourniquet is of value, in general, and more particularly in the case of the upper extremity, the employment of this means of controlling hemorrhage is to be avoided. In any event, if employed, it must be applied with the greatest care.

I wish to urge the employment of compression dressings, particularly as recommended by Neal Owens and ourselves. The essential features of our compression dressing are the employment of thick cotton waste, (4 to 8 inches), and the use of bias-cut flannel bandages. The latter should be at least 6 inches in width and, in our experience, have proved to be more useful than the various elastic bandages on the market. Needless to say, they are more durable and much less expensive.

SUMMARY

In the foregoing pages certain memoranda have been presented regarding surplus parts of the skeleton. An attempt has been made to show that a number of bones or portions thereof and, also, cartilages are not absolutely necessary for reasonably satisfactory functioning of the part.

It has been indicated that it is not the suggestion of the author that bones be indiscriminately removed but that, under certain circumstances, less disability is suffered and time is saved by skilful removal of damaged parts.

In this connection sixteen individual parts of the skeleton have been considered. It will be noted that, on the one hand, the indications for removal of certain parts are more positive than for others and, on the other hand, less disability follows the removal of certain structures than is the case with others.

With reference to the actual technic of excision certain memoranda have been made which, in the author's experience, have proved useful.

DISCUSSION

Paul B. Magnuson (Chicago, Ill.): First, I would like to say that I suspect my friend, Dr. Gurd, is accumulating a bone bank up in Montreal.

I think, when he speaks of parts being unnecessary, perhaps he would like some day to modify that to less essential for life, health and future happiness; in other words, I think we have to weigh whether the patient is going to have in this particular instance a longer or shorter disability as the result of one treatment or another, and whether the result in the future is going to make him more able to do his work, whatever it may be, than he would be if he were treated by some other method. That is a question of experience and judgment and I am sure that that is the way Dr. Gurd decides on the cases in which he considers removing certain parts of the skeletal system.

In regard to the menisci, I think we are all agreed that if they are properly removed and if they must be removed, they should be removed because they are acting as a foreign body, and a foreign body in any part of the body that is causing trouble should be and can be taken out. The menisci are probably the outstanding example of removal of a part in the skeleton or attached to the skeletal system that gives no bad results at all if the diagnosis is right and the removal was for the proper purpose.

On this clavicle business, I probably have been wrong for many years because I have always understood that fractures of the clavicle and dislocations of the acromioclavicular joint came as a result of the same mechanism applied in a different way, that is, the forcing of the shoulder toward the sternum, with additional force, in the case of dislocation of the acromioclavicular joint, applied on the arm in a downward direction and rather slowly; in other words, a man being thrown obliquely and the arm dragging down as the body is projected forward in the momentum.

I have been teaching my students that the function of the clavicle is to hold the shoulder backward and upward and add to the strength in lifting, and I do not think I am going to change my mind about that. It still is a prop between the sternum and the

shoulder. Of course that prop can be shortened and one can get along, really, without a lot of parts.

If we want to find out how people can do tricks in the absence of a lot of different muscle pulls, all that is necessary is to look at some of these little infantile paralytics that have had various muscles put out of business, and yet can do things that seem to be perfectly impossible. Not long ago I saw a man in one of the Navy hospitals who had completely lost the median part of his quadriceps and that fellow can do anything with his leg that anybody else can do. How he does it, I do not know. I always thought the quadriceps was an extensor of the knee and added great power. Well, he has the median part and the lateral part of the quadriceps but the medial part, that is, the middle part, is all gone.

One can get along, we know, with fewer parts. We know very little about the reciprocity of muscles, and when these people get along as well without a part as they did before, they probably have learned tricks that we have not learned to analyze as yet. And, incidentally, Dr. Inman out at the University of California has done some perfectly remarkable work on muscle function which I hope will be published very soon in connection with this work on artificial limbs that the Army and Navy and Veterans' Administration have been engaged in for the last few years.

This use of muscles in compensating for loss of skeletal structure, I think, is a thing about which we do not know very much. The resection of the acromioclavicular joint has been done many times and it simply takes off the pressure between two parts that are sore; and I certainly would not take the clavicle out because I had a dislocation of the clavicular joint, because that nice big ligament that runs between the coracoid and clavicle is quite an essential thing; and if that is repaired, it does not make much difference whether you have a little bit of ligament running between the clavicle and the acromion or do not. It is only when that ligament is torn that the clavicle really does displace upward, or rather the shoulder downward, and when the ligament is restored, the shoulder is held up.

The head of the radius—sure, take it out. But I do not believe in taking it out so far down that you do not have any bearing surface between the radius and the ulna because that limits the power of the muscles attached thereto. The lower end of the ulna is the same way. Dr. Davis used to say that the ulna should be considered as an extension of the arm downward and is concerned with motions of strength at the elbow; the radius, an extension of the hand upward and concerned with dexterity of the hand, so you can take out the ulna, at least the lower end of it. I noticed that in this boy that Dr. Gurd showed there actually had been developed another bearing surface between the radius and the ulna in the process of growth and he had a very nice lower radio-ulnar joint.

Now, certainly, you can move the hand with the lower end of the ulna gone, but you do not have too much strength in pronation and supination. But if you have a grip, you can use your upper arm muscles in pronation and supination.

Walter G. Stuck (San Antonio, Texas): Of course, like Dr. Magnuson, I can agree that many of these operations are useful such as excision of the patella, excision of the olecranon, excision of the clavicle, etc. I do find it difficult, however, to go along with Dr. Gurd on all of his excisions of bone.

My most obvious objection is to removal of the coccyx. It seems to me that this has been worked over many times. We all know that the coccyx is a sort of focal point for neuroses, and I have never seen anybody who has been disabled by an injury to the coccyx who was relieved by the removal of it. That is about the same way I feel about the small sesamoids under the first metatarsal head. If the sesamoid bones are injured, I doubt very much if the symptoms are relieved by their removal.

As far as condyles of the humerus are concerned, that is, of course, an open subject. It seems sometimes that replacement of the condyle and fixation with a screw might give a better functional elbow joint than would excision of a large fragment, such as you saw in the lantern slide.

The question of pain in the costal cartilages is very interesting to me because about thirteen years ago, I wrote a paper reporting eight fractures of the sternum and made the point that fractures of the costal cartilages caused symptoms long after the bone had healed. I had never thought of the possibility of reaction of the costal cartilage but that seems to make sense.

A new development in this field is the view nowadays about removal of comminuted fractures of the patella. Strangely enough, we have learned that we can get along well without the patella. Formerly we thought that the patella was absolutely necessary to normal knee function.

As I say, I can agree with probably 88 per cent of this paper, but about the remaining 12, I want to stay open to conviction.

Boardman M. Bosworth (Bronxville, N.Y.): I think there can be very little disagreement among us in general on Dr. Gurd's thesis. However, I am going to confine myself to the acromioclavicular joint.

It does not seem to me at all proper to remove the outer end of the clavicle for such a minor injury, which can very well be repaired in a minor fashion, and this I have tried to do in five instances. In all of those cases, you will have to take my word for it, the patients have excellent function and no complaints.

ROBERT H. KENNEDY (New York, N. Y.): It is always a pleasure to listen to Dr. Gurd and the various problems he has brought up have interested me for a considerable time.

Most of these procedures are well recognized as justifiable in certain instances, but like all things that are different, their indications are not recalled by surgeons in general as various cases arise. I think that is due to the lag in our thinking when it comes to adopting something that is a bit different from the way we have been brought up.

This presentation is particularly important because it reminds us that if a part might have to be excised at some time, the result will be much more favorable if we make up our minds on it right away and do it early rather than feeling that we are forced to do it later. This holds for adults only. We should not discuss children in this connection. I remember one unfortunate experience which I had, in which I believed I had to take out a badly comminuted head of a radius, and I always wished I had not done so.

I am coming to believe, in spite of Dr. Bosworth's pictures which we have just seen, that possibly the best result we can get in complete separation of the acromioclavicular joint is obtained by taking out the outer third of the clavicle.

With derangement of the superior radio-ulnar joint due to a fracture of the head of the radius, excision of the head and neck, extending just short of the biceps tuberosity is required. It should be done as soon as the x-ray findings show that you have a fracture which involves that joint. If it is done late, the results are often little, if any, better than without any operation at all. It is not worth doing unless you start mobilization immediately.

In the case in which there has been a failure of restoration of the inferior radio-ulnar joint following Colless' fracture, and the patient is complaining moderately, or bitterly, we too often forget that it is fairly simple to remove the distal fifth of the ulna with relief.

Dr. Gurd mentioned the scaphoid and semilunar. I have come to believe that instead of taking out the scaphoid and semilunar, it is better to go "whole hog" and take out the proximal row and be certain that the os magnum will be in contact with the radius. The wrist functions better than when part of the proximal row is left in.

In our efforts to appose the fragments in a simple transverse fracture of the patella, an irregularity of the level of the joint surface results too often. If we cannot restore the undersurface of the patella to its original position, it is more satisfactory to take out the patella with the proper suture following it. Of course, it seems to me there can be little question about the advisability of excision when one has a compound fracture or a comminuted fracture.

We all have an idea of the amount of disability which ensues from removing the fractured parts Dr. Gurd has mentioned. We would say that it is extremely little, or it is one-third, and so forth. If we see a patient in whom, as we analyze it, it seems that we would probably get a greater disability from conservative treatment than we have seen occur in a case in which a part was removed for some reason or other, we should remove that part as early as possible and not wait until we are forced to do it. To me, that is the great lesson in this paper—the time element.

HARRISON L. MCLAUGHLIN (New York, N. Y.): I am in complete agreement with the philosophy expressed by Dr. Gurd and we are indebted to him for this excellent paper.

I must admit to the absence of any mention of the costal cartilages in the article which he cited. A costal cartilage lesion sufficiently severe to warrant operative therapy has not yet been encountered on our service. I am glad to know that when such a lesion does occur symptoms can be relieved by excision and we will be on the lookout for these lesions from now on.

I would like to speak about removal of a portion of the acromion. Dr. Gurd's slide showed the excision to have been done through the acromioclavicular joint. It must be agreed that it is possible to do this with adequate resultant shoulder function, but we have found that when possible, it is advantageous to divide the acromion just lateral to the level of this joint. By so doing it is possible to remove almost as much acromion as if the excision had been done through the joint, and yet an intact bony and ligamentous girdle is left in the shoulder.

I would like to ask Dr. Gurd why the humeral head was removed in the fracture dislocation he described. Removal of the head fragment through a pectoral incision, although minimizing the risk of damage to the brachial plexus, could hardly have had an important bearing upon the resultant function of the shoulder. When possible, it would seem advisable to excise the humeral head fragment through an operative route which also exposes and makes possible a repair of the existing damage to the soft part machinery of the joint mechanism. In our experience functional results are best when this can be done.

I agree with Dr. Gurd that a partially executed removal of the clavicle does not interfere with its function as a prop. It is a disadvantage to remove the whole outer third of the bone since such a procedure separates the bone from its attachments to the coracoclavicular ligaments. The best results in our hands have followed upon an excision, the level of which was just lateral to the attachment of these ligaments. If not enough of the clavicle is removed certain patients have developed pain in the operative area on adduction of the arm.

LAURIE H. MCKIM (Montreal, Canada): If I may

be permitted just a moment, in answering the last speaker. Far be it for either Dr. Gurd or myself to suggest that the pictures shown of my case with the marked displacement of the head of the humerus, is the ideal procedure. This was a woman of about sixty-eight years, with a blood pressure of about 260. She weighed about 200 pounds and was only about 5 feet 5 inches tall. She had fallen downstairs. At the time that she was brought to the hospital, she had this very marked displacement of the head of the humerus. The head was removed as a minimal procedure, hoping that she might get *some* use of the shoulder joint. I hope that Dr. McLaughlin does not think that is our idea of what the removal of a head should be, or how it should be done.

I may say that the head was in a huge hematoma in the middle of the substance of the breast where it had gone along the sheath of the pectoralis major muscle.

Fraser B. Gurd (closing): I already indicated that it was not possible in the time at my disposal to cover the sixteen parts of the body plus the eight supplementary parts. If I have not been able to make certain points clear, I have already apologized in that regard.

It is unfortunate that Dr. Magnuson has had so little experience with cases which would allow him to learn the function or lack of function of the clavicle. The removal of the whole clavicle either for the exposure of the thoracic dome or of the brachial plexus or for purposes of operating on the subclavian, has been done sufficiently often by a number of different surgeons, including myself, to be certain that the clavicle has no function other than as a point d'appui for the muscles attached to it; and if, when the clavicle is removed, care be taken to attach the muscles which were previously fixed to the posterior or superior portion to those having their origin from the inferior border of the clavicle so that each acts as a point of fixation for the other, then there is no disability.

I have x-rays of individuals, farmers, belonging to a family in which nine male members are without clavicles. They work with a horse-drawn plow in the spring; in the wintertime, they fell trees; in the summer, they pitch hay. The fact that the clavicle is not very useful is proved, I think, by cases of that sort.

I think it was four years ago that through the correspondence portion of "Life," which had pictures of a gentleman who had no clavicle, it was made clear that there was interest in this matter because within the next week, I received about twenty copies of "Life" from different parts of the country. It is just a matter of passing of time, I feel sure, before Dr. Magnuson will have had enough experience with the clavicle to realize the uselessness of this part of the anatomy.

In a published article seven years ago on the subject, Dr. McLaughlin, I indicated that I determined the point of division of the clavicle by slipping my finger underneath the bone and when I met the ligament, I stopped and divided the bone at that point. Among other things, this experience has proved to me that the ligaments between the coracoid and the clavicle have very rarely been torn. They are intact even in cases in which there is complete dissociation of the acromioclavicular joint.

I already indicated, gentlemen, that it would take me a long time to read everything I have written and I purposely made the matter sketchy. I have no intention, even if the Chairman would allow me to do so, to go back and cover the whole ground all over again.

I want to thank Dr. Stuck for agreeing with me 85 per cent. Very few things I have ever suggested ever got anything like that agreement! That is really, I think, perfectly marvelous.

Dr. Kennedy has always been known for his graciousness, and I appreciate his kind remarks. If he is anxious to remove more parts than I am, I will not argue with him. Quite clearly, these memoranda do not apply to children, particularly with reference to the radial head.

FURTHER OBSERVATIONS ON PENETRATING WOUNDS OF THE HEART AND PERICARDIUM*

CHARLES HUGH MAGUIRE, M.D. AND R. ARNOLD GRISWOLD, M.D.
Louisville, Kentucky

IN 1941, the above authors reported forty-seven cases of penetrating wounds of the heart and pericardium.[1] In that group, there were twenty-seven patients who were alive twenty minutes after admission to the accident ward and who allowed time for definite diagnosis and definitive treatment. There were seven deaths in that group with a mortality of 25.9 per cent. The group that we are presenting at the present includes an additional thirty-three cases admitted to the hospital with the diagnosis of a cardiac wound. In any southern city of any size with a high percentage of negro population, the incidence of wounds of the heart will necessarily be high. In this group of thirty-three cases there were: four white males; six colored females; one white female, and twenty-two colored males.

Injuries to the heart and intrapericardial portions of the great vessels may be caused by any sharp instrument or projectile that may enter the thoracic cage. In this series the most frequent offending articles in the order of their frequency of occurrence were: knife, pistol and ice pick. There were twenty-four knife wounds, six gunshot wounds and three ice pick wounds. It must be remembered by the staff in the accident ward that wounds of the heart and great vessels may be caused by an injury in practically any quadrant of the chest or may be reached by an injury to the upper abdomen; however, the more frequent site of injury is in the left chest from the second interspace to the seventh intercostal space within the nipple line. It must also be remembered that the heart may be reached by a relatively short knife through the mid-axillary line or from a posterior wound. The portion of the heart that is most frequently injured is the right ventricle because of its anterior position even though a large part of the ventricle is protected by the sternum. Next in frequency come the left ventricle, the auricles and the aorta in this order. (Figs. 1 and 2.)

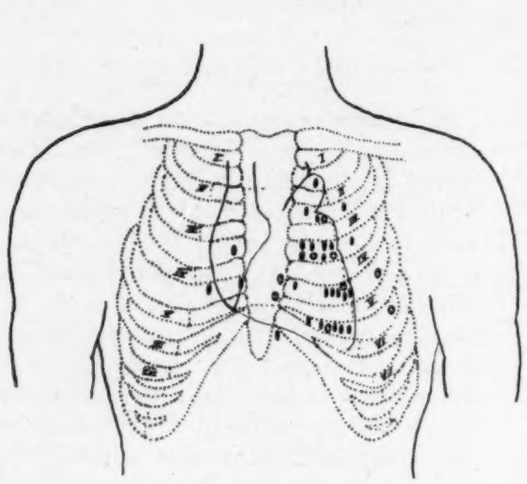
PATHOLOGY

Following a wound to the heart of any consequence, one of two things begin to happen. There is the immediate production of either acute cardiac tamponade or rapid exsanguination. In order for acute cardiac tamponade to occur the wound in the pericardium must be relatively small and the wound in the heart and the amount of bleeding from the heart muscle, chamber or vessel must be relatively brisk. If the amount of bleeding is such that the opening in the pericardium cannot decompress it rapidly enough, either into one of the pleural cavities or to the outside, acute cardiac tamponade with the findings of Beck's triad[2] will be found. In one of our cases there had been complete obliteration of the left pleural cavity due to a previous acute pleurisy. This patient had a large wound in the chest wall and a small laceration of the tip of the right ventricle. He had all of the signs of acute cardiac tamponade. He had apparently decompressed through the wound in the chest slowly but enough to prevent death from tamponade before surgery could be instituted.

If the wound in the pericardium is large and the pleural cavities are patent, relatively rapid exsanguination may occur. In the majority of the patients in this series who died before surgery could be instituted, death was due to exsanguination and most of them either had multiple wounds of the heart or single large wounds of one of the chambers of the heart with a large enough wound in the pericardium to allow free bleeding into one or both of the pleural cavities. If the wound in the chest wall is large enough fatal hemorrhage may occur to the outside. It is believed by the authors that cardiac tamponade at times will be a life saving factor, as most cases of cardiac tamponade will allow time for diagnosis and treatment. The amount of blood that is necessary

* From the Department of Surgery of University of Louisville School of Medicine and Louisville General Hospital, Louisville, Ky.

to produce acute cardiac tamponade varies directly with the rapidity of bleeding from the heart. In the rapidly bleeding case with a very small wound in the pericardium only 200 cc. may be enough to produce a fatal tamponade. In the case in which the bleeding from the heart is relatively slow, the pericardium may be gradually stretched so that it may accommodate 400 or 500 cc. before serious compression of the heart occurs.



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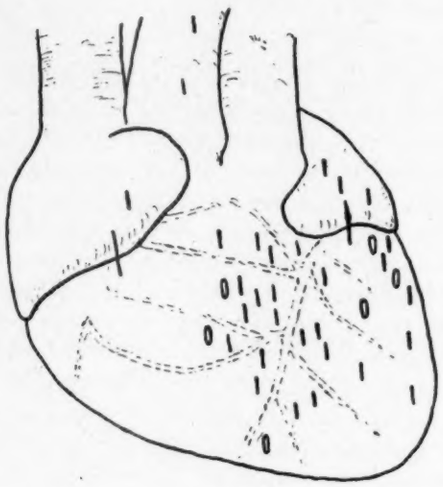

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FIG. 1. Diagram showing external wounds in the chest wall.
FIG. 2. Diagram showing wounds of the heart muscle and intrapericardial portions of great vessels.

Cerebral emboli may occur secondary to mural thrombi that have formed at the site of the wound in the endocardium. In one case (A-2) of the present series five of the chordae tendineae had been severed in the right ventricle and there had also been perforation of the interventricular septum. There were mural thrombi at the sites of the perforations in the ventricles and the septum as well as on the stumps of the chordae. This patient died on his third postoperative day with definite evidence of cerebral embolism. There is another complication that should be mentioned here and that is continued bleeding from the heart wound even after apparent successful suture. In case (A-15) in which there were through-and-through wounds of the right and left ventricles secondary to a twenty-five caliber bullet, apparently successful suture of both wounds was carried out. At the time of closure of the chest both of the wounds were apparently dry, although the operator made the observation that there was a tremendous amount of bruising of the muscle about both wounds. This patient died on his second postoperative day, secondary to what was apparently slowly progressing hemorrhage. Both pleural cavities had filled repeatedly with fluid that was an admixture of blood and serum, which was tapped repeatedly. In spite of repeated transfusions, the patient died about fifty hours after surgery. Gelfoam, or some such similar substance, would have been of tremendous benefit in this case but this will be taken up later in the paper.

DIAGNOSIS

Diagnosis and successful institution of surgical treatment in wounds of the heart and pericardium depends on several factors. The foremost of these is the education of the house staff and more particularly the members of the team in the accident ward in quick recognition of a wound of the heart. An alert staff must remember that a wound of the heart can occur in practically any penetrating wound of the chest or the upper abdomen. In practically all cases of cardiac wounds the general condition of the patient and the presence of shock will be out of all proportion to the extent of the obvious wound. If acute tamponade is present, the classical triad of Beck[2] will present itself in the form of low or falling arterial pressure, high or rising venous pressure and a quiet heart. The patient will be bathed with profuse perspiration and usually will be in varying degrees of delirium. As brought out in our other series,[1] acute alcoholism is usually present and that in itself will occasionally

slightly confuse the clinical picture. Pulse rate is surprisingly slow unless there has been considerable hemorrhage into the pleural cavities or to the outside. If there is time for a direct measurement of the venous pressure in the anticubital space and fluoroscopy, the diagnosis may be definitely established. In acute cardiac tamponade there will be an increase in venous pressure to levels of 250 mm. or above. Fluoroscopy will show widening of the cardiac shadow and greatly diminished or absent pulsation of the pericardial shadow. When there is a large wound of the heart and an equally large laceration of the pericardium so that active and free bleeding may occur into the pleural cavities, the venous pressure will be normal or even lower than normal and the examination of the chest by fluoroscopy may show only evidence of a large amount of fluid in one or both of the pleural cavities. If this is found and it is known that the time of the injury has been within the previous several hours, exploration of the thorax is imperative. Laceration of the lung tissue as a rule does not produce massive hemorrhage in a short period of time. With one or both of the pleural cavities partially filled with blood, it must be recognized that there is active bleeding occurring which must be arrested. Fatal hemorrhage can and does occur from lacerations of the internal mammary vessels or from one or more intercostal vessels.

TREATMENT

Many of our cases have been sent directly from the accident ward to the operating room because of recognition of a cardiac wound by the staff without preliminary determination of venous pressure or fluoroscopy; however, it might be added here that this is the only phase of our treatment of cardiac wounds that is hurried. There is no sacrifice of aseptic surgical technic. The team which scrubs for the operation goes through the routine scrub that is customary for any elective procedure and the thorax is prepared just as carefully with adequate shaving, cleansing with green soap, saline, ether and a suitable surface antiseptic. We have rigidly standardized this procedure, even though the enthusiasm of the resident to "get into that chest" might encourage him to take some short cuts. As a direct result of this, we have had only one infected case in the past fourteen years. This patient developed infection of the skin flaps and osteomyelitis of the end of the resected ribs. There have been no cases of pericarditis or empyema.

There is little or no premedication given as most of these patients are comatose and need no sedatives or narcotics. We have omitted narcotics from the preoperative regimen because of the depressing effect on respiration. If time allows, the patient is typed and cross-matched for transfusion on the way to the operating room. Intravenous fluids may keep the pressure of the patient up if there has been massive hemorrhage but in the presence of acute cardiac tamponade there is little if any benefit to be derived from fluids or plasma.

There is little to be said about the choice of anesthesia as most of these patients need oxygen under positive pressure at the beginning of the operation and do not need an anesthetic agent until tamponade has been released. After operation has been begun the anesthetist may begin to feed in a little nitrous oxide. We believe that cyclopropane should not be used because of the effect of the cyclopropane on the irritability of the heart. Positive pressure must be continued after opening of the pleural cavity and continued until the chest is closed.

At this point, in regard to irritability of the heart, one small technical maneuver might be mentioned. Quite frequently during manipulation or rotation of the heart, during or after sutures are placed, the rhythm of the heart will become very irregular. This irregularity is very easily controlled by the use of 1 per cent novocain sprayed over the surface of the heart. Within a space of seconds the irregular rhythm will become regular and further manipulation may be carried out.

The choice of the type of incision has undergone a gradual change at this hospital over the years. In some of the earlier cases the classical Spangaro incision was used but this was discarded for the "T"-type incision. The cross bar of the "T" is placed along the left side of the sternum and the lateral limb of the "T" placed over the rib nearest the wound of entrance. In this type of incision there would be two "L"-shaped flaps dissected up which would naturally open more space for potential infection. In the past six years we have used a nearly horizontal incision placed over the rib nearest the wound of entrance. This incision has been advocated by Elkin and in our hands has been found to be most satisfactory. If there is need for more exposure, the costal cartilages

of the ribs above and below the resected rib may be cut through and more exposure may be obtained. If there has been careful examination of the wound of entrance, a definite idea of the direction of the knife, bullet or ice pick may be obtained so that through experience the place-

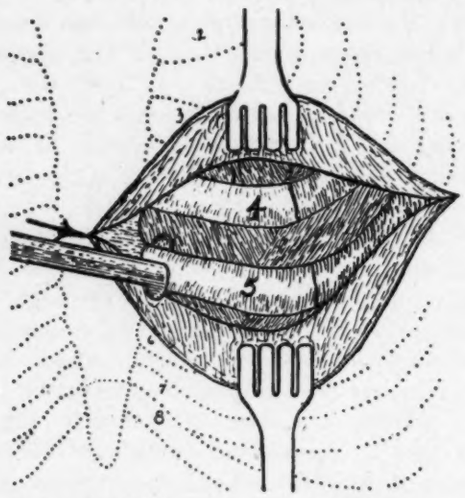

FIG. 3. Diagram giving transverse incision placed over the rib to be resected.

ment of the incision will become most adequate. The rib should be stripped from the sternum outward as shown in (Fig. 3), as stripping in this direction is easier and also quicker. If the pleura has not been damaged, an effort should be made to strip the pleura away from the pericardium; however, with the patient under positive pressure anesthesia, entering of the pleural cavity will be of little consequence. A small nick is then made in the bulging pericardium or the original wound is spread widely with the fingers. An effort to cut the pericardium with a knife or scissors may result in unnecessary injury to the underlying myocardium as it is found in many of these cases that the right ventricle will be directly beneath the pericardium. This is apparently due to the "floating" action of the blood and clots in the pericardial sac.

After opening of the pericardial sac the liquid blood is quickly aspirated into an auto-transfusion outfit. A tremendous amount of blood may be salvaged, both from the pericardial sac and the pleural cavities in this manner. In one case in this series there were 2,500 cc. given by auto-transfusion and in another there were 1,900 cc. given by auto-transfusion. The subject of auto-transfusion has been adequately covered by Griswold and Ortner[3] from this institution. Free clots are scooped out by the finger tips and a search is made for the wound in the heart. If the wound is anterior, brisk bleeding and increased activity of the heart will make the wound apparent as soon as the tamponade is released. If the wound is not apparent immediately, the method advocated by Beck[4] should be carried out and a silk suture should be placed through the apex of the heart for traction. This suture will steady the heart while search is made. A word of caution was put into our previous report in that the traction suture must be relaxed with each contraction of the heart or the suture will cut through the heart muscle and the operator will have to deal with two lacerations of the heart muscle instead of a single one. Further traction sutures may be placed either to the right or left of the original traction suture for rotation of the heart. The heart can apparently be rotated almost 90 degrees without damaging circulation through the systemic or pulmonary systems.

When the wound of the heart is found, the tip of one or more fingers may be placed over the wound until satisfactory sutures can be placed. After one or more sutures are placed, traction or crossing of the placed sutures will control hemorrhage until all of the sutures can be secured. As we brought out before, none of the sutures should be deep enough to penetrate the endocardium because of the possibility of thrombi forming at the points of perforation of the endocardium.

To the inexperienced surgeon or staff member a wound of the auricle will frequently present quite a problem. The wall of the auricle may be so thinned out that the placement of one or more sutures will only result in two more pinpoint perforations that will bleed with each contraction of the auricle. The use of Gelfoam or some such similar substance, as advocated by Jenkins[5,6] may provide the answer to this problem. The substance may be tied over the bleeding points or may possibly be held over the bleeding points until adherence occurs within several minutes. In case (A-23) our resident found after placement of adequate sutures in a wound of the right ventricle that there was considerable oozing, both from the laceration and from the suture holes. A piece of Gelfoam was tied over the bleeding points with satisfactory control of the troublesome oozing.

After control of the bleeding from the laceration of the heart or great vessels a suitable opening is made from the pericardial sac into either the right or the left pleural cavity for decompression of the pericardial sac. After any manipulation of the heart there is a definite outpouring of serous fluid and this in itself is enough to cause serious embarrassment of the heart if the pericardium is closed without drainage into one of the pleural cavities. None of our cases have been drained to the outside. We believe that drainage into one of the pleural cavities is adequate for decompression of any heart wound. We have not used drainage to the outside in any of our cases because we believe that a drain to the outside invites infection from the outside into the pericardial sac. The one case in which there was obliteration of both pleural cavities there was a drain placed from the pericardial sac into the subcutaneous tissues, which was removed on the second postoperative day after a satisfactory vent had been established.

The chest wall is then closed in layers with interrupted silks under positive pressure. There is rather meticulous care taken in the closure so that there will be no problem of subcutaneous emphysema or subcutaneous collection of fluid.

Postoperatively, all these patients are placed in an oxygen tent, using eight to ten liters a minute. The patient is usually placed in a high Fowler's position as this is more comfortable and probably materially assists respiration. Unless there has been massive hemorrhage and a large per cent of the blood has not been given back via auto-transfusion, postoperative transfusions are not needed.

As pointed out above, in two of the cases 2,500 and 1,900 cc. were given back to the patient. Opiates are used sparingly since it is necessary for these patients to have as full an expansion as possible to assist in re-expansion of the left lung. A careful check must be made of the left thoracic cage periodically to discover pneumothorax or hemothorax before embarrassment of respiration takes place. In the average case one to two paracenteses twelve and thirty-six hours postoperatively usually takes care of any residual pneumothorax or exudate into the thoracic cage.

The patient is removed from the oxygen tent as soon as respiration and pulse approach normal. Serial electrocardiographs are taken as soon postoperatively as feasible and the electrocardiograph tracings will determine to a large extent when the patient should be allowed up. It has been our experience that relatively trival heart wounds will give electrocardiographic tracings that will seem much more serious than the actual heart wound. It has been observed in wounds of the right ventricle near the atrioventricular groove without definite damage to the left coronary or to the anterior descending branch of the left coronary that there will be tracings consistent with a diagnosis of anterior infarction. Patients without damage to a major vessel or without extensive lacerations in the ventricles or auricles may usually be allowed out of bed within a week and out of the hospital within fifteen to twenty days.

CASE REPORTS

During the past six years thirty-three cases of wounds of the heart have been admitted to the Louisville General Hospital. In this group there have been twenty-three cases which have allowed time for diagnosis and treatment. Three of the patients died on the operating table before the chest could be opened. Seven expired between the time they were brought to the accident ward and were taken to surgery. The majority of the patients who were operated upon have been done by the chief resident at the time. The following are short résumes of each of the twenty-three patients operated upon:

Case A-1. T. S., a colored male, age thirty-seven, was admitted sixty minutes after a stab wound in the fifth intercostal space to the left of the sternum. His blood pressure was 60/40; pulse 90; the venous pressure was increased. Fluoroscopy showed enlarged cardiac shadow. The patient was explored through a "T" incision, excising fourth and fifth costal cartilages. A lacerated wound of the right ventricle was found and sutured. The patient made an uneventful recovery and was discharged on the twenty-sixth hospital day.

Case A-2. A. M., a colored female, age twenty-eight, was admitted an hour and thirty minutes after injury with a knife wound in the fifth intercostal space. Her blood pressure was 40/0; venous pressure and fluoroscopy were not done. The patient was opened through a "T" incision. A 1½ cm. laceration of the right ventricle was found, which was sutured. The patient died on the third postoperative day and autopsy revealed that five chordae tendineae had been severed. There had also been perforation of the interventricular sep-

tum. There were multiple mural thrombi over the wounds in the endocardium, as well as over the stumps of the chordae. Twelve hours prior to death the patient developed acute symptoms of cerebral embolism.

Case A-3. V. D., a colored male, age forty-two, was admitted sixty minutes after injury with a stab wound in the second intercostal space to the left of the sternum. His blood pressure was 0; pulse 80. Fluoroscopy revealed enlarged cardiac shadow. Exploration through a horizontal incision placed over the stab wound revealed a laceration of the aorta and right ventricle. The laceration was sutured and the patient was discharged on the twenty-first hospital day.

Case A-4. W. P., a colored male, age 30, with no history, was admitted with a stab wound over the third intercostal space to the left of the sternum. His blood pressure was 0; pulse 80; venous pressure 200 mm. of water. Fluoroscopy revealed enlarged cardiac shadow. The patient was explored through a horizontal incision over the fourth intercostal space. A laceration of the right ventricle was found and sutured; 1,900 cc. of blood were given to the patient via auto-transfusion and he was discharged on the twenty-fifth hospital day.

Case A-5. V. S., a colored female, age nineteen, with no history, was admitted with a stab wound in the fifth intercostal space, 5 cm. to the left of the sternum. Her blood pressure was 0; pulse 90; venous pressure 220 mm. of water. Fluoroscopy showed enlarged cardiac shadow. The patient was explored through a horizontal incision over the fourth rib. A wound of the right ventricle was found and sutured. The patient was discharged on the twenty-second hospital day.

Case A-6. B. C., a white male, age forty-four, with no history, was admitted with a wound over the fifth intercostal space, 6 cm. to the left of the sternum. His blood pressure was 0; pulse 90; increased venous pressure and widened cardiac shadow. He was explored through a horizontal incision over the fourth rib to the left of the sternum. A wound of the right ventricle was found and sutured and he left the hospital on the sixteenth postoperative day.

Case A-7. F. W., a white male, age fifty, with no history, was admitted with a gunshot wound of the third intercostal space to the left of the sternum. His blood pressure was 0; pulse imperceptible; increased venous pressure and widened cardiac shadow. The patient was explored through a "T" incision over the fourth rib. A jagged wound of the right ventricle was found and sutured. This patient received 2,500 cc. of blood via auto-transfusion. He left the hospital on the twenty-fourth hospital day.

Case A-8. M. R., a colored male, age twenty-three, was admitted twenty minutes after injury with a wound in the second intercostal space to the left of the sternum and another wound in the midclavicular line in the same intercostal space. His blood pressure was 0; pulse imperceptible; venous pressure 210. Fluoroscopy was positive for increased cardiac shadow. The patient was explored through a "T" incision over the third rib and a laceration of the left ventricle was found and sutured. He was discharged on the eighteenth hospital day.

Case A-9. W. B., a colored male, age thirty, admitted fifteen minutes after injury with a wound in the fourth intercostal space to the left of the sternum. His blood pressure was 50/30; pulse 60; fluoroscopy was positive. The patient was explored through a "T" incision over the fourth rib. A laceration of the left ventricle was found and sutured and he was discharged on the fourteenth hospital day.

Case A-10. C. B., a colored male, age thirty, with no history, was admitted with a penetrating wound in the midline just below the tip of the xiphoid process. His blood pressure was 60/20; pulse 70; increased venous pressure and widened cardiac shadow. The patient was explored through a horizontal incision, removing a fragment of the sixth costal cartilage. A wound of the right ventricle was found and sutured and the patient was discharged on the nineteenth hospital day.

Case A-11. W. C., a colored male, age twenty-three, with no history, was admitted with a blood pressure of 70/40; pulse 70; increased venous pressure and widened fluoroscopy shadow. When the patient was explored through a horizontal incision over the fifth rib, a wound of the left ventricle was found and sutured. He was discharged on the twentieth hospital day.

Case A-12. J. W., a colored male, age twenty-seven, was admitted fifteen minutes after injury with a wound at the fourth intercostal space to the left of the sternum. The blood pressure was 0; pulse imperceptible; increased venous pressure and wide cardiac shadow. The patient was explored through a "T" incision over the fourth rib and a laceration of the right ventricle was found and sutured. He left the hospital on the eighteenth hospital day.

Case A-13. W. T., a colored male, age fifty, was admitted fifteen minutes after injury caused by a stab wound of the third intercostal space to the right of the sternum. His blood pressure was 0; pulse 80. Fluoroscopy revealed an enlarged cardiac shadow. The patient was explored through a horizontal incision to the right of the sternum and a laceration of the right ventricle was found and sutured. He was discharged on the twenty-third hospital day.

Case A-14. R. R., a white male, age twenty-three, was admitted with a gunshot wound of the fourth intercostal space to the left of the sternum.

His blood pressure was 80/60; pulse 80. Exploration through a horizontal incision to the left of the sternum revealed a jagged laceration of the right ventricle which was sutured. He was discharged on the thirtieth hospital day after an uneventful recovery.

Case A-15. J. S., a colored male, age twenty-seven, with no history, was admitted with a gunshot wound just above the tip of the xiphoid. His blood pressure was 0; pulse 80. Fluoroscopy revealed an enlarged cardiac shadow. The patient was explored through a horizontal incision over the fifth rib to the left of the sternum. Exploration of the heart revealed a through-and-through wound of the right and left ventricles. The wounds were sutured but the patient died on the second postoperative day, apparently of gradual, continuous bleeding.

Case A-16. J. K., a colored male, age forty-five, was admitted sixty minutes after a stab wound in the third intercostal space to the left of the sternum. His blood pressure was 0; pulse indiscernible; venous pressure increased. Fluoroscopy showed increased cardiac shadow. The patient was explored through a horizontal incision over the fourth rib to the left of the sternum and a wound of the left auricle was found and sutured. He made an uneventful recovery and was discharged on the twenty-fourth hospital day.

Case A-17. C. T., a colored male, age twenty-nine, with no history, was admitted with a stab wound in the fifth intercostal space, 3 cm. to the left of the sternum. His blood pressure was 60/0; pulse 90 per minute; venous pressure was not taken. Fluoroscopy revealed enlarged cardiac shadow. The patient was explored through a "T" incision, removing the fourth rib. A wound of the right ventricle was found and sutured. He made an uneventful recovery and left the hospital on the twenty-fifth day.

Case A-18. G. C., a colored male, age thirty-five (?), was admitted thirty minutes after injury with a 1½ cm. stab wound in the fourth intercostal space to the left of the sternum. His blood pressure was 20/0; pulse 80. Fluoroscopy revealed an enlarged cardiac shadow. Exploration through a transverse incision revealed a 1 cm. laceration of the left auricle, which was sutured. Convalescence was uneventful and the patient was discharged on the thirtieth hospital day.

Case A-19. W. M., a colored male, age twenty-two, was admitted thirty minutes after injury with a knife wound in the third intercostal space to the left of the sternum. His blood pressure was 0; pulse 100; venous pressure 180 mm. of water. Fluoroscopy revealed a markedly enlarged nonpulsatile cardiac shadow. The patient was explored through a horizontal incision placed to the left of the sternum. A laceration of the right ventricle was found and sutured. He was discharged on the twenty-eighth hospital day.

Case A-20. E. R., a colored male, age sixty-five, was brought into the accident ward with no definite history. He had received a stab wound of the second intercostal space to the left of the sternum. His blood pressure was 0; pulse 80. Fluoroscopy revealed an enlarged cardiac shadow. The patient was explored through a left horizontal incision over the fourth intercostal space, and a laceration of the left ventricle was found and sutured. He was discharged on the twenty-fourth hospital day.

Case A-21. R. V., a white male, age forty-eight, was admitted thirty minutes after injury with a knife. He had a wound in the fourth intercostal space to the right of the sternum. His blood pressure was 0/0; pulse barely discernible. Fluoroscopy revealed an enlarged cardiac shadow. Exploration through a "T" incision in the fourth intercostal space revealed a 2 cm. laceration to the right of the right auricle. Convalescence was uneventful and the patient was discharged on the nineteenth hospital day.

Case A-22. E. B., a colored female, age twenty-two, with no history, was admitted with a stab wound in the first intercostal space to the left of the sternum. Her blood pressure was 0; pulse unattainable; venous pressure and fluoroscopy were not done. The patient was explored through a "T" incision, removing fragments of the second and third costal cartilages. A wound of the left auricle was found and sutured. She left the hospital on the seventh postoperative day.

Case A-23. D. F., a colored female, age twenty-eight, was admitted approximately thirty minutes after injury with a knife wound in the third intercostal space, just to the left of the sternum. A wound high on the right ventricle was found and sutured. Gelfoam was sutured over this laceration because of troublesome oozing. The patient made an uneventful recovery and was discharged on the thirteenth hospital day.

Case B-1. C. M., a colored male, age thirty-nine, was admitted sixty minutes following a gunshot wound of the left chest just lateral to the nipple. His blood pressure was 0; pulse 100 per minute; venous pressure and fluoroscopy were not done. The patient was explored through a "T" incision placed over the left fourth rib. He expired before the pericardium was opened from tamponade plus massive hemorrhage. There were wounds of the left ventricle, left auricle and pulmonary vein.

Case B-2. C. T., a colored male, age thirty-two, with no history, was admitted with a gunshot wound just above the xiphoid. His blood pressure was 0; pulse 90; venous pressure done on the operating table, while team was scrubbing, was 150.

The patient expired as surgery was being started. Autopsy revealed a through-and-through wound of the right ventricle with massive hemorrhage.

Case B-3. T. H., a colored male, age thirty-five, with no history, was admitted with a stab wound in the fourth intercostal space. He expired on admission to the accident ward. No autopsy was attainable.

Case B-4. C. L., a colored male, age thirty-seven, with no history, was admitted with a wound in the third intercostal space 6 cm. to the left of the sternum. The patient expired on admission to the accident ward and no autopsy was obtained.

Case B-5. M. C., a colored female, age forty-five, with no history, was admitted with a massive wound of the left chest, involving the third, fourth and fifth costal cartilages. She expired on admission to the accident ward.

Case B-6. W. B., a colored male, age thirty, with no history, was admitted with a gunshot wound of the second intercostal space 5 cm. to the left of the sternum. The patient died on the way to surgery. Autopsy revealed a through-and-through wound of the right ventricle and right auricle.

Case B-7. C. L., a colored male, age thirty-seven, with no history, was admitted with a stab wound in the third intercostal space 6 cm. to the left of the sternum. The patient expired on the way to surgery. Autopsy revealed a wound of the right ventricle.

Case B-8. M. C., a colored female, age fifteen, with no history, was admitted with a gunshot wound of the fifth intercostal space. She expired before the chest could be opened. There were through-and-through wounds of the right and left ventricles.

Case B-9. C. P., a colored male, age thirty-five, with no history, was admitted with a wound in the anterior axillary line. The patient expired before surgery could be started. Autopsy revealed a wound of the left ventricle.

Case A-10. Q. B., a white female, age thirty-two, was admitted with an ice pick wound in the fourth intercostal space just to the right of the sternum. The pick was still in place. Her blood pressure was 60/0; pulse 120; venous pressure, taken on the operating table, showed 220 mm. of water. As the chest was being opened through a transverse incision over the fourth rib, the patient went into ventricular fibrillation and expired. Autopsy revealed a jagged wound of the right and left ventricles.

SUMMARY

This series of penetrating wounds of the heart and pericardium includes twenty-three patients with cardiac wounds who were alive twenty minutes after admission to the hospital which allowed time for diagnosis and surgery. There were two postoperative deaths in this series, one on the third and one on the second postoperative day. This presents a postoperative mortality of 8.69 per cent. (Table I.) All of the patients who died on admission to the accident ward, expired on the way to the operating room or before surgery could be started died from exsanguination.

Table I

1941–1947

Cases admitted	33
Operated cases	23
Postoperative deaths	2
Mortality	8.69%

In our previous paper of 1941, we reported forty-seven cases of penetrating wounds of the heart and pericardium with a mortality of 25.9 per cent. (Table II.) This present series includes an additional thirty-three cases admitted with the diagnosis of cardiac wounds. This gives a total number of eighty cases in which the presumptive diagnosis of wound of the heart or pericardium was made. In this overall group there were twenty-three patients who died before surgery could be instituted. There were seven cases in the original series in which the presumptive diagnosis of a cardiac wound was not borne out at operation. Three had evidence of tampanode due to pressure of extrapericardial hematomas. In two there were massive hemorrhages into pleural cavities from large vessels, and in one there was a laceration of the pericardium and diaphragm but not of the heart. The seventh case has been discussed in detail by Badertscher.[7] There were fifty cases that allowed time for diagnosis and treatment with nine deaths, or an overall mortality of 18 per cent. (Table III.)

Table II

1933–1941

Cases admitted	47
Operated cases	27
Postoperative deaths	7
Mortality	25.9%

Table III

1933–1947

Cases admitted	80
Operated cases	50
Postoperative deaths	9
Mortality	18%

This decrease in the postoperative death percentage is a direct result of several factors. As brought out earlier in this paper, one factor

is education of the house staff and the staff in the accident ward so that immediate recognition of a cardiac wound is made and the patient is sent to surgery with a minimum of delay. A second factor that is of extreme importance is the teaching of the Chief Resident in Surgery

TABLE IV
1938–1947

Operated cases	36
Postoperative deaths	3
Mortality	8.33%

the technic of dealing with cardiac wounds so that surgery may be begun within twenty or thirty minutes after admission to the hospital rather than having to delay operation until the Chief of Staff or some other member of the staff interested in these cases comes "across town." An interval of fifteen to thirty minutes may mean the difference between life and death to the patient. In this series and the series reported previously, the Chief Resident at the time did more than 75 per cent of the cases. A third factor that is of importance is an operating suite that is open and ready twenty-four hours a day with a major setup ready and sterile at all times. During the time that the team is scrubbing up, the nurse in charge may quickly sterilize any special instruments that may be needed in a cardiac wound in one of the high-speed instrument sterilizers that are available today. The importance that these factors play in the successful treatment of cardiac wounds is reflected in the fact that in the last thirty-six patients with cardiac wounds who were alive twenty minutes after admission to the accident ward, which allowed time for diagnosis and treatment, there were only three deaths with a mortality of 8.33 per cent. (Table IV.)

The most frequent cause of death in the postoperative cases has been cerebral embolism secondary to mural thrombi forming at the sites of perforation of the endocardium. It might be mentioned here that there is probably a place for the use of some of the anticoagulant drugs postoperatively when the surgeon is reasonably sure that there has been perforation of the endocardium. It is believed by the authors that in any wound of the auricles some form of anticoagulant should be used. In any wound of the auricles it is practically impossible to place sutures without entering the auricular cavity. The use of heparin has been mentioned previously by Bigger.[8]

We also believe that there is another important usable material that has been introduced into this field in the form of Gelfoam, or some similar substance, as has been advocated by Jenkins. Many of the wounds of the ventricles that continue to ooze may be controlled with the use of one of these substances and it has a very definite place in the treatment in wounds of the auricles.

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DISCUSSION

LOUIS G. HERRMANN (Cincinnati, Ohio): Dr. Maguire and Dr. Griswold have presented a remarkable group of patients with wounds of the heart and pericardium. They have covered their subject so well that there is little that I can add so I shall re-emphasize some of the things they have already presented. We are convinced that injuries to the heart and great blood vessels occur sufficiently often in wounds of violence that a thorough re-evaluation of our surgical methods and our physical equipment for the proper management of these injuries should be made by all of us.

It is absolutely essential that the resident surgeons of our larger hospitals remain alert at all times for such vascular injuries since too much delay in carrying out definitive treatment always means failure to save the life or the limb of the injured person. In the discussion of injuries to large blood vessels which was presented yesterday, we emphasized the fact that proper supportive treatment with whole blood and fluids will usually permit even extensive surgical procedures in patients with injuries to the heart or large blood vessels without serious complications if the basic principles of vascular surgery are constantly observed during the operation.

Prompt diagnosis of the site and kind of injury with as little delay as possible in transporting the patient to the operating room is an essential part of definitive treatment. The operation itself should not be hurried and we must never permit improper preparation of the operative field in the quest for speed. Serious wound infection with secondary chondritis has followed such neglect of proper preparation of the skin of the thorax before operation.

I must emphasize the importance of the use of a solution of novocain on the surface of the exposed heart. This simple procedure will permit the handling of the heart without causing the rhythm to become seriously altered. We have also observed that the irritability of heart is greatly reduced by this simple measure and in several cases in which the injury caused serious irregularity of the heart action the application of novocain to the surface of the heart restored normal rhythm promptly and the operation could then be completed without further difficulty.

Dr. Griswold and his associates should be commended for the fine work which they have done during the past decade in the management of wounds of the heart. In Cincinnati we have observed more injuries to large blood vessels and fewer injuries to the heart. We believe, however, that the surgical problems are the same for all such vascular injuries.

Much progress has been made during the past ten years in this field of vascular surgery and we must now alter our attitude toward such injuries and insist that they receive immediate and adequate care. We should analyze the facilities for the management of such injuries in all the hospitals in which we work and we must make every effort to acquaint our younger surgeons and particularly our resident surgeons with the principles upon which success in vascular surgery is based. We will save many lives and many limbs if we remain alert to these important surgical emergencies.

James M. Winfield (New York, N. Y.): It is indeed a great pleasure and honor to discuss the most interesting presentation of Dr. Griswold and Dr. Maguire. In a review of thirty-two cases at the Detroit Receiving Hospital, it will be found that the method of production or causation of these injuries very nearly parallels that of the authors, with this difference: We had a relatively higher degree of wounds from ice picks than from gunshot and we had a smaller total number of gunshot wounds. We had no infections but had one very serious effusion, this occurring in a patient who had the right pulmonary artery injured. This artery was injured from a wound that came from the left side, about half-way between the mid-portion of the sternum and the nipple.

I think the mortality that the authors have reported is amazing. Our mortality, overall mortality, was 22.2 per cent. In the diagnosis, naturally, every patient has to be individualized, but there are certain things that I think should be emphasized: One is the history of what happened to this patient when he was injured. The shock is usually out of all proportion to the evident wound. Frequently, if you get them early, you will see very profuse bleeding from a small wound over the cardiac area and that should make one suspicious.

There are several points which I would like to emphasize. I certainly agree that there is no excessive "rush" about operating upon these patients. That is a relative thing. But the business of driving them up to the operating room and performing a heroic surgical procedure on a moribund patient is not usually necessary or wise. Time, as a rule, can be taken to carry out supportive measures. We have lately been performing more pericardial taps. We had three patients who were injured by ice picks that were tapped once (each one of them only once), and we decompressed the tamponade. The patients had all the signs and symptoms of tamponade to a small degree but it was present. They recovered without any difficulty.

Dr. Blalock, Dr. Bigger, Dr. Churchill and others have emphasized that pericardial tap to decrease the tamponade is often a life-saving measure, and if you withdraw the blood and at the same time start giving them blood and preparing the patients for operation, their condition may be immeasureably better when you get in there.

Another point is anesthesia. I emphasize anesthesia because without positive pressure anesthesia, that is, under local or improperly given inhalation anesthesia, the operation is tremendously difficult as compared to this type of operation when good anesthesia is given under positive pressure.

A high oxygen content with nitrous oxygen oxide is the best anesthesia.

We do not sew the pericardium but drain it into the pleural cavity. It is remarkable that patients who suffer severe cardiac wounds have so few sequelae after recovery from the operative procedure. As a rule, they are able to carry on their usual work, and from this standpoint repair of the injured heart gives very gratifying results.

Again, I would like to say how much I appreciated hearing this paper.

Charles Hugh Maguire (closing): I certainly appreciate Dr. Herrmann's and Dr. Winfield's remarks. There is one thing I would like to reemphasize that Dr. Winfield emphasized, and that is, the tremendous come-back that many of these people make, even with relatively extensive cardiac wounds.

I mentioned a while ago that we routinely run postoperative electrocardiographic tracings on

these people as soon as feasible. One interesting observation that has completely upset our cardiologists has been the finding that in relatively trivial wounds of the right ventricle, close to the atrioventricular groove, without apparent damage to any of the major coronary vessels, practically a 100 per cent will have tracings which are consistent with anterior infarction. That finding will persist frequently for a matter of a week or ten days and then gradually return to normal.

The cardiac reserve in these people, even when they have had extensive wounds of the myocardium, is tremendous. Most of these colored boys are common laborers and, of course, drunks on Friday and Saturday, but they return to their hard labor without any evidence of residual cardiac damage. One boy in our previous series, that we are reporting separately later, had complete division of his left coronary. I do not know whether you remember the original wound slide, but there was one heart wound which entered both the left auricle and left ventricle and had severed his left coronary. The wound actually was big enough for me to put the tips of two fingers into it and the tip of the third finger as a plug while we were placing the sutures. On the operating table, the entire anterior surface of the right ventricle became cyanotic; there were circus movements in this cyanotic area. Novocain controlled these irregular contractions. He had electrocardiographic findings consistent with massive anterior infarction. That finding persisted for as long as two months. However, he gradually reverted to a normal electrocardiogram and at the present time, which is about five years postoperatively, he has been back to hard manual labor for a matter of four years.

I appreciate the discussion, and it has been a pleasure to be here.

USE OF CUTIS GRAFT MATERIAL IN THE TREATMENT OF TRAUMA AND ITS RESULTS

JOHN E. CANNADAY, M.D.
Charleston, West Virginia

OUR understanding is that cutis is skin from which an epidermal layer of very moderate thickness has been removed (usually with a skin graft razor). Cutis possesses great value as replacement material in the course of the repair of traumatic or other defects in aponeurotic structures in various parts of the body; in the repair of certain fractures such as those of the patella; for the binding together of certain longitudinal long bone fractures, it is a superior substitute for the Parham band; it constitutes satisfactory plastic repair material for use in the Nicola or Henderson type of operation for the relief of chronic recurrent types of shoulder dislocation.

Technic. For quite some time we have been using alloy stainless steel wire for the purpose of closing defects in the aponeurotic structures, likewise for suturing the cutis graft into position.

Hernia. The aim in general in regard to hernial repair and reenforcement is to make the best possible closure under the conditions present, after which the reenforcing layer is applied snugly. Not infrequently a modified plastic operation (lipectomy) of the abdominal wall in the immediate area of the hernia improves the contour considerably. A pressure dressing of mechanic's waste usually is applied and kept in place for ten days to two weeks.

As repair and replacement material cutis possesses many advantages such as ready availability, prompt healing in, apparent absence of foreign body reaction. It may be used in as many layers as may be needed to give adequate strength.

In regard to its use for ligation of the large vessels (arterial or venous) our use indicates that cutis is in every way satisfactory for this purpose.

Technic for Ligation of Large Vessels. The strip of cutis is carried twice around the vessel, clamped in that position, and held firmly with a curved hemostat while transfixion cotton ligatures are placed and tied so as to secure the strip of cutis firmly against any possibility of slipping. By contrast, ligatures of rubber, likewise those of cotton tape, may cut through a large vessel.

From the standpoint of trauma, use of cutis graft material has been made by some of my surgical associates and me for the replacement of aponeurotic tissues that have been destroyed in various areas of the body, clinically seen as defects in the aponeurotic layers of the abdominal wall; for the repair of destroyed areas of dura incidental to gunshot wounds or other causes (Case I); for the control and alleviation by stage, also immediate, ligation of the common carotid artery, certain types of cerebral aneurysms (Cases II and III); for the ligation of large veins (for instance, the vena cava) incidental to the treatment of thrombosis and embolism (Cases IV and V); for approximation of the third and fourth metacarpal bones in clawhand; for the surgical treatment of ankylosis of the jaw; in the reduction of sternoclavicular dislocation (Cases VIII and IX); in the treatment of unstable knee (Case VII); for the repair and reenforcement of ruptured muscle sheaths (Case VI); for the repair of certain types of hernia; for the repair of diastasis of the buccinator muscle (glass blower's hernia); in the reduction of fracture of the patella; in the treatment of fracture of the ulna; in the reduction of acromioclavicular dislocation; for the repair of contour defects over depressed areas in the frontal bone and for implantation graft after sequestrectomy for chronic discharging sinus of the foot.

CASE REPORTS

CASE I. E. A., a male, white, age fifteen, was admitted to the Charleston General Hospital after having received a shotgun charge (bird shot) at close range in the right temporal area. There was considerable destruction of the soft tissue, bone, dura and brain.

Operation was performed by Dr. A. A. Wilson and Dr. Joseph Haber. The dural rent was cleansed by irrigation and débrided; it was closed by a cutis graft patch 1 inch (2.5 cm.) square. A sliding flap of adjacent scalp was brought down and sutured

in place so as to cover the large defect in the skin. The result has been very satisfactory.

Case II. Mr. J. B. S., age sixty-two, white, complained of ringing in the ears and of a painful and pronounced exophthalmos of the left eye. He had fallen down a flight of steps in a hotel twenty-seven days prior to admission to the hospital and apparently had suffered severe concussion. There was complete left ophthalmoplegia with pronounced exophthalmos and extreme edema of the conjunctiva. No evidence of intracranial pressure was noted. The patient remembered none of the events of the accident. There was a loud bruit which could be heard all over the forehead and adjacent areas of the head but perhaps was heard best around the left eye; hence, it was assumed that the patient had an arteriovenous fistula.

Operation was performed January 31, 1945, by Dr. A. A. Wilson, on whose service the patient was admitted to the hospital. An incision was made in the left side of the neck and carried downward so as to expose the common carotid artery just below its bifurcation. A rubber-shod clamp was applied to the carotid artery for twenty minutes with no untoward reaction. A ½ inch (1.3 cm.) wide strip of cutis was wrapped twice around the common carotid artery and held sufficiently taut to obliterate, almost but not completely, the pulsation. The strip was anchored firmly in position with interrupted cotton thread sutures. At that point in the operation it was noted that the bruit ceased immediately. The wound was closed in layers with fine silk.

Eight days later the wound of the previous operation was opened and the carotid artery exposed. Three ligatures of heavy black silk were tied tightly around the encircling strip of cutis, after which the weak pulsations distal to the cutis ligature ceased. The wound was closed in layers with fine black silk.

Doctor Wilson states that this patient has recovered completely. There has been no return of the bruit and the exophthalmos in the left eye has disappeared entirely.

Case III. M. P., a colored female, age thirty-one, was admitted to the Charleston General Hospital on the neurologic service, complaining of pain over the right eye and ptosis of the right eyelid. The diagnosis of cerebral aneurysm, anterior cerebral artery, was made.

Operation was performed May 27, 1947, by Dr. Charles J. Harkrader, Jr., chief surgical resident. Cutis graft ligation of the common carotid artery was done and the patient was relieved of her symptoms almost immediately.

Case IV. Mrs. A. T., a white female, age sixty, complained of a painful left leg due to thrombophlebitis of numerous veins of the left leg and thigh which had occurred following a week in bed with influenza. Ligation of the vena cava was decided upon.

Operation was performed April 7, 1947, by Dr. John E. Cannaday. The vena cava was exposed retroperitoneally through a lower abdominal transverse incision, and a short length mobilized by finger dissection. The vena cava then was ligated with a strip of cutis passed twice around it and anchored with double No. 30 cotton thread sutures. The patient's symptoms were relieved at the time she left the hospital, April 25th, and she stated that she was feeling well.

Case V. G. H., a white male, age sixty-four was admitted to the second medical service of the Charleston General Hospital, April 25, 1947, with thrombophlebitis of the right leg and pulmonary infarction of the right side of the chest. In spite of treatment with dicumarol the patient's temperature continued to run septically and vena cava ligation was decided upon.

Operation was performed April 29, 1947, by Dr. John E. Cannaday. An incision was made in the right flank at the level of the umbilicus. The vena cava was exposed retroperitoneally by blunt dissection and isolated at the level of the bifurcation of the aorta. A strip of cutis was carried twice around the vena cava, drawn snugly and firmly anchored with interrupted cotton thread sutures. At the time of the patient's discharge from the hospital (May 11th) his condition was quite satisfactory.

Case VI. S. F., a white man, age forty-five, was admitted to the Charleston General with a history of severe trauma to the calf of the right leg after which a painful bulge developed on the back of the injured leg below the knee. The hernial bulge was about 2¼ by 2¾ inches (6 by 6.9 cm.). A cutis graft repair was done by Dr. John E. Cannaday. The patient had an apparent good result following the primary operation, but later sustained a secondary injury of the leg involved, with apparent recurrence of some of the previous symptoms. At a second operation the aponeurotic structures of the calf of the leg were resutured with apparent satisfactory results to date.

Case VII. Miss D. W., a white woman, age nineteen, was operated on November 30, 1944, by Dr. George Tsunekawa and the writer for the reconstruction of the crucial ligaments of the knee. The crucial ligaments were repaired with a heavy strip of cutis graft material. Immediate results were excellent and, according to a report from her physician several months ago, her condition still was excellent, with normal function.

Case VIII. B. S., a white male, age not noted, was operated on by Dr. George Miyakawa October 18, 1944, for the cutis graft repair of a dislocation of the right sternoclavicular joint. A cutis strip was passed through a previously made quarter-inch drill hole in the superior portion of the sternum, then introduced in the previously made somewhat similar hole in the proximal end of the

clavicle. The two ends of the graft then were sewed back on the graft under considerable tension with cotton thread sutures. The result in this case has been very satisfactory.

Case ix. R. R., a white male, age not noted, was operated on September 19, 1945, by Dr. George Miyakawa for the repair of a right sternoclavicular dislocation. The cutis graft technic, as reported in the preceding case, was followed, and the results have been excellent.

COMMENT

The ligations of the vena cava reported in Cases iv and v were done with a view to the alleviation of an ascending thrombosis and embolism involving the right leg and thigh. Cutis tissue was used as ligature material in both of these cases. Since thrombosis and embolism not infrequently follow traumatism of the lower extremities, it was thought advisable to report these ligations. It has been observed that the structures of the vena cava are rather fragile. Special care, therefore, must be taken in order to prevent injury of this vessel.

CONCLUSIONS

As I have concluded in previous reviews of our experience with cutis, its greatest value probably lies in its use as a reenforcing graft in the treatment of certain types of hernia. However, it is of great value in the reconstruction of joints, also when used for reenforcement and replacement purposes in the repair of ruptured ligaments of the knee. It has been found to be excellent material for the stage or immediate ligation of large arteries.

SURGICAL TREATMENT OF IRRADIATION DERMATITIS AND CARCINOMA

D. M. GLOVER, M.D.
Cleveland, Ohio

IRRADIATION injuries to the superficial tissues may be divided into the following categories: 1. Acute burn; 2. chronic dermatitis and 3. chronic ulcers with malignant degeneration.

The damage to tissue may result from exposure to x-irradiation or radium emanations. Injuries result usually from misuse of these agencies but in some instances proper dosage of carefully calibrated x-rays or radium has produced disastrous results. Just why a given dosage of irradiation will produce only erythema and pigmentation of the skin in one patient and chronic dermatitis with malignant ulceration in another is difficult to explain. It seems inescapable that individual variations in susceptibility must explain these unusual instances.

The underlying pathologic process is fundamentally the same in the various categories of irradiation effect. In the acute burn there is necrosis of the skin with adjacent areas of edema and cellular infiltration, comparable to that found in a superficial burn due to any other agent. In the chronic states, however, perivascular infiltration becomes apparent and it is the progression of this process which leads to further necrosis, followed by fibrosis and still more perivascular round cell infiltration. It is apparently the repeated ulceration and healing of skin which is poorly vascularized which eventually produces a malignant change.

ACUTE BURN

Treatment of the acute x-ray or radium burn is largely medical. The following cases illustrate the types of acute irradiation necrosis which require surgical intervention.

CASE I. A man fifty-six years of age was treated by external x-irradiation for a fungus infection of the palm of the hand and fingers. He was accidentally given a longer exposure than planned. Within a few days the entire palmar surface of the hand and fingers became beefy red, edematous and extremely painful. Within the next three weeks the entire palmar skin became necrotic and gradually sloughed. There was at first some tendency for the cutaneous margins to show evidence of epidermal proliferation but gradually this ceased and further necrosis took place. At the end of two months the palmar aspect of the hand and fingers was completely denuded of skin and fascia and the tendons presented masses of necrotic slough. The hand at this stage was extremely painful and the patient frequently required opiates for relief. At this stage it was obvious that the entire palmar skin, fat, fascia, flexor tendons, nerves and intrinsic muscles had been destroyed. Since any sort of plastic reconstruction could not possibly provide a useful hand amputation was performed in the distal third of the forearm.

CASE II. A male sixty-nine years of age received seven x-ray treatments for "plantar warts" on the left foot. When seen some six months later he presented a necrotic ulcer 3 cm. in diameter on the plantar surface of the foot, centered over the metatarsophalangeal joint of the middle toe. The ulcer was surrounded by a 1 cm. areola of dense, avascular scar. The base of the ulcer was painful on direct pressure but showed no tendency to bleed.

Comment. X-ray burns of the type illustrated in Case II, involving as they do a weight-bearing surface, are among the most difficult to treat successfully at any age but particularly so when the added handicap of peripheral arteriosclerosis is also present. A certain number of these burns will heal in younger individuals with bed rest, lack of weight bearing and mechanical cleansing and will remain healed if the plantar surface of the foot is judiciously padded to prevent pressure upon the callous which inevitably forms at the point of closure. If, however, the ulcer fails to heal or remain healed under such conservative management, one of the following methods of treatment is advised: (1) Excision, wide undermining of the surrounding plantar skin and closure; (2) Excision and application of free grafts; i.e., either thick-split grafts or multiple, small, deep grafts "nested" or packed closely together and (3) Excision and pedicle graft from the opposite leg.

Of the three methods enumerated the first

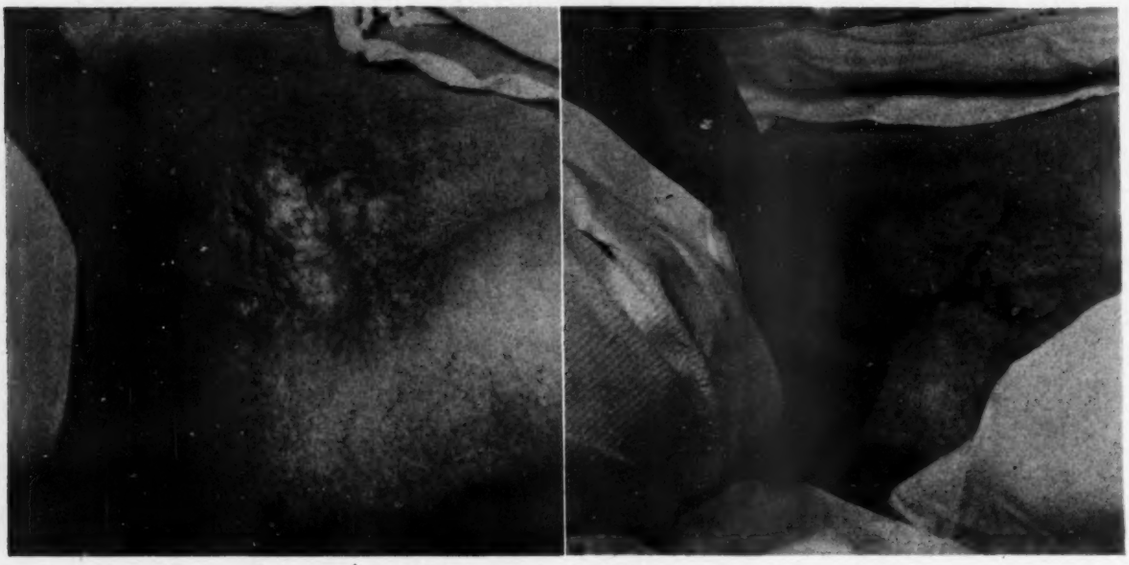

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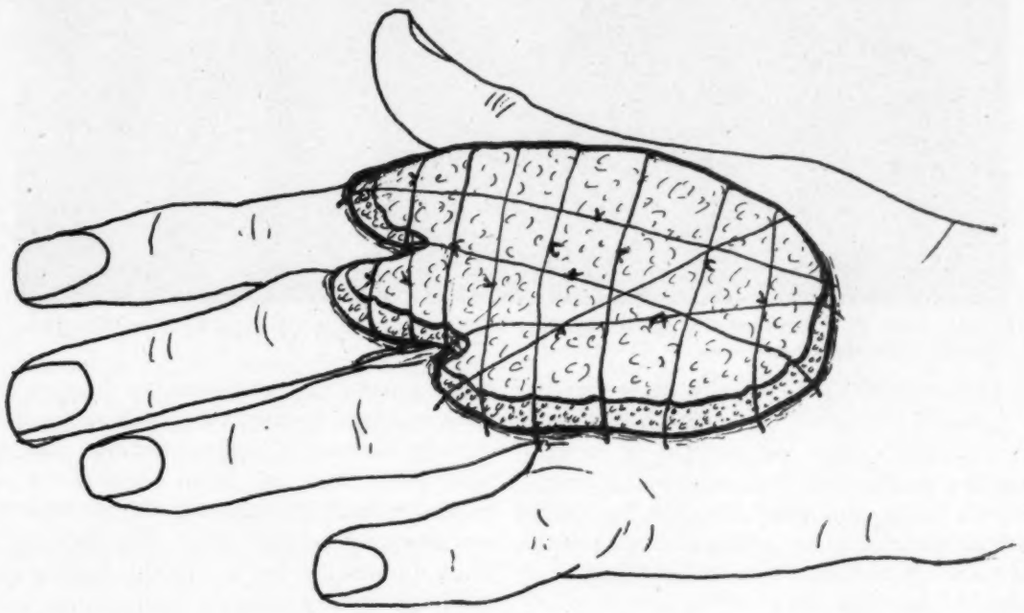
FIG. 1. Case III. Irradiation dermatitis of the supraclavicular region.
FIG. 2. Case III. The area of dermatitis has been excised and closed in inverted "Y," by sliding flaps of normal skin.

FIG. 3. Case IV. Irradiation dermatitis of the left hand twelve years after treatment of benign cutaneous lesions.

is the simplest and usually merits a trial before resorting to a graft. The avascular scar must be adequately but not widely excised and the undermining of plantar skin must be wide enough to allow easy approximation of the edges without any tension. In addition to fine approximating sutures several tension sutures should be placed and left in place until the edges are completely healed. Fine tantalum wire sutures applied in vertical mattress form and tied over buttons of tantalum foil cause little tissue reaction and may be left in place for three weeks. Weight bearing should be avoided for three or four weeks and after that time the line of closure protected with felt pads. If primary excision and closure fails, a free graft is worth a trial because of its relative simplicity but few free grafts are permanently

satisfactory on the sole of the foot. A pedicle flap from the opposite leg offers the best opportunity for satisfactory closure of the ulcer but the following disadvantages are inherent in the method: (1) long immobilization of the extremities is hazardous in older individuals who have a tendency to develop restriction of joint movement; (2) the transplanted skin does not always tolerate weight bearing well and (3) callosities tend to form at the junction line between the margins of the flap and the surrounding plantar skin. For the reasons enum-



A

FIG. 4. A, Case IV. Sutures about the margin of the dermatome graft have been tied over rubber sponge cut accurately to fit the defect.

B

FIG. 4. B, Case IV. The appearance of the dermatome graft is shown immediately after removal of the sponge rubber on the sixth postoperative day.

FIG. 5. Case IV. Comparison of the grafted hand (left) with the uninvolved hand (right) three months after operation.

erated pedicle grafts are usually reserved for those patients in whom other methods have failed. During the first few months of weight bearing on a plantar flap its cutaneous covering may break down at pressure points but with meticulous cleanliness, a well fitted shoe and careful padding the skin finally toughens and will tolerate constant use.

CHRONIC IRRADIATION DERMATITIS

Chronic skin changes may follow immediately upon the healing of an acute x-ray or radium burn or may appear years after the treatment was received without intervening symptoms or signs. Frequently the dermatitis appears within a few months of treatment and is continuous. The skin changes are characterized by the shiny, tense, mottled appearance, with many telangectases and often areas of atrophy with scattered brownish pigmentation. The involved skin shows lack of elasticity and blanches when under tension. At first, pain is not present but with passage of time and thickening of the involved skin, pruritis is almost constant. In those areas which finally become malignant pain is often very severe. Areas of irradiation dermatitis which have been present for years tend to form vesicles and cracks which, subsequently, crust while the telangectases occasionally bleed. When the latter changes appear malignancy should always be suspected.

MALIGNANT ULCER

The indolent ulcer in an area of irradiated skin is likely to prove malignant, although many persist for years without showing malignant change. Microscopic section is the only certain method of differentiation. The malignant lesion may vary from a superficial ulceration to a deep, penetrating ulcer with irregular margins and necrotic base. The isolated ulcer often proves to be a prickle cell carcinoma although it may occasionally show characteristics of both basal and squamous cell lesions. The typical basal cell carcinoma occurring in irradiated skin is prone to occur in papules or multiple nodules which tend to coalesce and ulcerate superficially. The latter are often more difficult to treat because of their tendency to invade superficial fascial planes and extend beyond the area of cutaneous involvement. The basal cell lesions are also more likely to occur in irradiated skin which has shown no previous changes many years after the treatment was given. Regional lymph node involvement by the carcinoma is unusual and disseminated metastases are rare. Several patients have been observed with irradiation carcinoma over a period of years without lymph node involvement. Radical surgical removal of the local lesion and the irradiated areas offers the patient a good prognosis. Although statistics are few it is the opinion of the author that the prognosis of the squamous cell carcinoma arising in irradiated skin is somewhat better than that of the basal cell carcinoma.

SOURCES OF IRRADIATION

The diagnosis for which irradiation was given in the patients observed by the author has been varied. Following is a partial list

which does not include numerous, small, irradiated scars which were simply excised:

Plantar warts	10
Dermatitis of face	5
Dermatitis of hands	5
Pigmented nevi	5
Carcinoma of breast (postoperative)	5
Lupus of face and neck	4
Vascular nevi	4
Uterine fibroids	3
Keloids from burns	3
Hypertrichosis	2
Mixed tumor of parotid	2
Portwine nevus	1
Sterilization	1
Benign breast tumor	1
Perineal epidermophytosis	1

X-irradiation was given in the majority of patients, radium in a few. Treatments were given by general practitioners, dermatologists and radiologists. The time interval between irradiation and surgical treatment varied from three months to thirty-five years.

RATIONALE OF SURGICAL TREATMENT

The removal of areas of irradiated skin is indicated in some instances for purely cosmetic reasons and in others because of pain or dysfunction of the affected part. The prophylactic removal of areas of irradiation dermatitis, especially those showing evidence of ulceration, is advisable. No reliable statistics are available to indicate the true incidence of carcinoma in areas of irradiation dermatitis but our impression is that the eventual incidence is high. That is to say, the patient with a large area of severe irradiation dermatitis probably stands a better than even chance of developing carcinoma if he lives long enough. The majority of the malignant lesions we have treated occurred from ten to thirty-five years after irradiation. The following cases illustrate the problems of surgical treatment:

Case III. *Benign irradiation dermatitis of the neck:* The patient, a female of fifty years of age, received external irradiation for treatment of a breast lesion fifteen years ago and the lower cervical region was included in the field. There had been an area of unsightly dermatitis in the lower cervical and supraclavicular regions on the right side for several years but within the past year it had thickened, become itchy and the telangectases had occasionally bled. The patient presented a mottled area of atrophic skin in the lower cervical and right supraclavicular region about 12 cm. in diameter. (Fig. 1.) This area was excised and closed in an inverted "Y" after mobilizing adjacent flaps of normal skin. (Fig. 2.) Microscopic section showed no evidence of malignancy.

Comment. Single or multiple excisions of irradiated skin are practical in the neck and abdominal wall when the surrounding skin lends itself to wide undermining and mobilization of flaps. The cosmetic result of such excisions is better than replacement with free grafts.

Case IV. *Benign irradiation dermatitis of the hand:* Fifteen years prior to observation, the patient, a man of thirty-five years of age, had received external irradiation for dermatitis of the left hand. In the past two years an area of mottled, telangectatic, atrophic skin covering most of the dorsum of the hand and fingers had thickened and was prone to crack frequently with hard use or exposure to extremes of temperature. (Fig. 3.) Because of the hazard of malignancy in a region exposed to constant trauma, excision and free graft were advised. Most of the skin of the volar surface of the hand was excised down to the areolar layer over the extensor tendons. A dermatome graft of 16 micra thickness was cut from the inner aspect of the thigh and shaped to fit the defect, the graft being cut on the dermatome drum about 10 per cent larger than the defect. The graft was sutured into the defect, the sutures being left long and they were tied over a piece of sponge rubber cut to fit the defect exactly. At the end of six days when the sponge rubber was removed the graft was completely vascularized. (Figs. 4A and B.) At the end of three months the appearance of the skin ws practically normal. (Fig. 5.)

Comment. Dermatome grafts are ideal for resurfacing the dorsum of the hand and they take well even on an irradiated base if the cicatricial tissue is completely removed. It is important to set the grafts in under slightly less than normal skin tension if maximum elasticity is to be obtained. It is also desirable that the margins of the defect be regular and that the graft be sutured meticulously to them with the finest suture material available. The sutures may be either continuous or interrupted. When the sponge rubber technic is used it is advantageous to place sutures every 1 to 1.5 cm. and to leave long enough ends to tie over the rubber.

SPONGE RUBBER TECHNIC

To insure a perfect "take" of a free graft on an irregular surface, it is axiomatic that the graft must be maintained in complete apposition to the base for at least two days. For the past ten years we have found sheets of sponge

FIG. 6. Case v. Irradiation dermatitis with ulceration in a port-wine nevus.

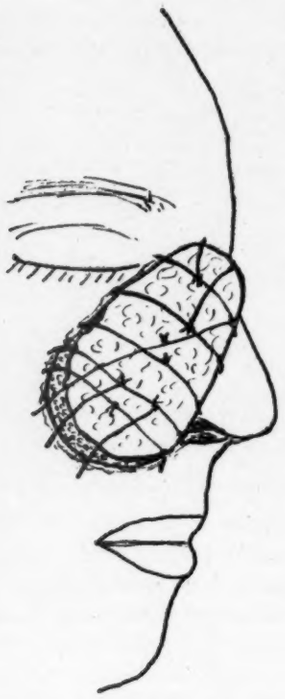
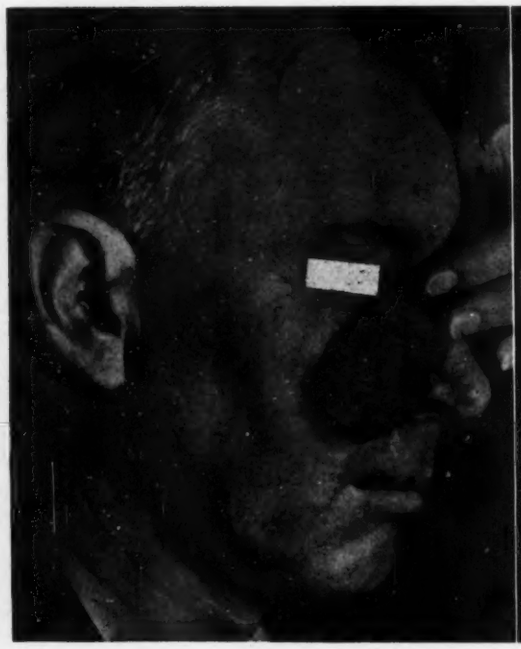


FIG. 7. A, Case v. Sutures about the margin of the dermatome graft tied over sponge rubber cut to fit the defect.



7B

8

FIG. 7. B, Case v. Photograph showing the sponge rubber still in place after removal of sutures.
FIG. 8. Case v. Appearance of the dermatome graft after removal of the sponge rubber mold on the seventh postoperative day.

rubber ideal for this purpose. Sponge rubber of even texture is selected from which an elastic mold may be cut which exactly corresponds to the contour of the defect. The sponge rubber molds vary in thickness from 1 to 2.5 cm. depending upon the depth of the defect. One or two layers of plain cotton bandage gauze are placed between the graft and the rubber sponge to avoid sticking. The suture ends are tied loosely over the rubber mold thus providing complete fixation. Part of the sutures are cut at the end of two or three days to obviate tension due to edema and the sponge rubber is peeled off in from five to seven days. This method has been found particularly useful in repairing defects on the face and hands when other methods of fixation are likely to fail. (Figs. 4A and 7A.)

Case v. *Irradiation dermatitis in a portwine nevus:* A male patient, fifty-five years of age, received external irradiation for a portwine nevus of the right side of the face ten years before our observation. For the past two years an area on the right side of the nose and cheek had broken down repeatedly. This area had been curetted and biopsied several times by a competent dermatologist but had failed to heal completely. The biopsies had been negative. Because of the threat of malignancy and the inconvenience of repeated ulceration, excision and skin graft seemed indicated. (Fig. 6.) The area of maximum irradiation damage, together with some of the most obvious surrounding portwine nevus, were excised down to the facial muscles and replaced with a thick dermatome graft. Figure 7 shows the area covered with the sponge rubber mold after removal of the sutures while the appearance of the grafted area at seven days is shown in Figure 8. Microscopic sections of the excised skin showed no evidence of malignancy. At this time the grafted skin, while not a perfect match, had already begun to blend well with the surrounding skin and seemed to justify the use of a thick dermatome graft rather than a full-thickness free graft or pedicle flap.

Comment. In the case just recorded a pedicle graft of skin by means of a temporal flap or a cervical flap would have provided more nearly ideal skin for replacement, but these were decided against by the preference of the patient and the time and economic factors involved in such procedures, realizing that a free graft might give less perfect replacement. A thick dermatome graft was used in preference to a free full-thickness graft from the postauricular region because of the size of the graft required and the fact that a thick dermatome graft applied as herein described provides skin of almost equal texture with less hazard of skin loss. The use of a cosmetic preparation to match the color of the grafted skin to the normal and to minimize the borders of portwine nevus remaining make its presence scarcely obvious during the months required for the new skin to assume approximately normal color. If its final color is not perfect, pigment tattooing may be used to improve the match. In the case described it seems improbable that this will be necessary.

Fig. 9. Case VI. Large irradiation ulcer of the cheek twelve years after treatment of mixed tumor of the parotid. A cervicothoracic flap has been prepared to fill the defect after resection. The ulcer was benign.

Case VI. *Chronic irradiation ulcer of cheek:* A female patient, fifty-seven years of age, received external irradiation on the left cheek and neck following removal of a mixed tumor of the left parotid gland twelve years prior to admission. For two years prior to admission there had been a large, painful area of granulation over the margin of the left mandible, cheek and submaxillary region which had responded to none of various methods of treatment. A large, avascular ulcer presented, approximately 6 by 10 cm., on the left cheek and submaxillary region across the mid-portion of which the margin of the mandible stood out in relief although covered by granulations. A cervicothoracic flap was prepared in stages (Fig. 9), the entire necrotic area was excised together with the margin of the mandible and the distal end of the flap was set into the anterior end of the defect. The remainder of the defect was covered temporarily with a dermatome graft from the thigh until the proximal end of the flap could be turned around to cover the defect adequately. The microscopic

FIG. 10. Case VII. Malignant irradiation dermatitis of the right hand following treatment for fungus infection.

FIG. 11. Case VII. Comparison of uninvolved and grafted hands six months after operation.

sections showed no evidence of malignancy much to the surprise of the author.

CASE VII. *Malignant irradiation dermatitis of the hand:* A male patient, fifty-five years of age, received superficial x-irradiation for a fungus infection of the hand over a period of fifteen years. The first time the patient was observed he presented an area of extensive irradiation dermatitis involving most of the dorsum of the hand, with most marked changes on the radial side. There were several areas of superficial ulceration and one fairly deep ulcer on the dorsum of the web space between the thumb and index finger. (Fig. 10.) The area of involved skin was excised and replaced with a thick dermatome graft. After six months the grafted region was scarcely distinguishable from the normal skin on the uninvolved hand. (Fig. 11.) Microscopic sections of the skin removed showed changes typical of squamous cell carcinoma in the deeper ulcer. The prognosis is good.

CASE VIII. *Basal cell carcinoma in multiple irradiated areas on the face:* A male patient, thirty-

12 13

Fig. 12. Case VIII. Basal cell carcinoma of the chin and cheek in an area irradiated during the treatment of pigmented nevi thirty-three years before. A thoracic flap has been prepared to fill the defect after resection of the involved skin.

Fig. 13. Case VIII. Appearance of the same area shown in Figure 12 five years after resection and replacement by flap.

five years of age, received radium treatments in infancy for multiple congenital pigmented nevi. First seen in 1941, he presented multiple papillary excrescences and superficial ulceration in irradiated areas of the right temporal region and the left cheek over the body of the mandible. Biopsy confirmed the presence of basal cell carcinoma in both regions. The involved skin in both regions was widely resected. The defect in the right temporal region was replaced with a scalp flap while a delayed thoracic tube flap was employed to fill the defect on the left cheek. The appearance of the latter lesion before excision, with the thoracic tube prepared, is shown in Figure 12 and the completed flap in Figure 13. The original areas were free from recurrence five years later but new areas were beginning to appear in other treated regions of the face. From one of these, biopsy showed basal cell carcinoma.

Case IX. *Basal cell carcinoma of the nose in region previously irradiated for lupus:* A male patient, fifty-eight years of age, received irradiation by x-ray for lupus of the nose and cheek thirty-five years before the date of first observation. At that time he presented an irregular ulcerative lesion of the left ala of the nose extending to the septum and nasolabial fold. The involved skin was resected together with considerable surrounding skin, mucous membrane, septal cartilage and alar cartilages. The defect was immediately filled by means of a previously lined temporal artery flap. The resected ulcer proved to be a basal cell carcinoma which had involved the full thickness of the ala and margin of the septum. The nasal reconstruction was not entirely adequate from an esthetic standpoint but the patient was satisfied. He has remained free from recurrence for eight years.

Case X. *Squamous cell carcinoma of the neck and cheek following irradiation for lupus:* A sixty-seven year old male patient received extensive x-irradiation for lupus of the face and neck over a period of twelve years prior to first observation by the author. At this time he presented a large, necrotic ulcer on the right side of the neck with a crater about 4 cm. in diameter. (Fig. 14.) The lesion was so painful that the patient had threatened suicide. It was apparent that the sternomastoid muscle and the deep cervical nodes were involved. The ulcer was widely resected together with the sternomastoid muscle, the internal jugular vein and the deep cervical nodes. The defect was filled by a flap swung from the back. Microscopic sec-

FIG. 14. Case X. Squamous cell carcinoma of the neck and cheek following irradiation for lupus. Radical resection was done and replacement with flap from back.

tions showed a moderately well differentiated squamous cell carcinoma in the ulcer and the deep cervical lymph nodes. Two years later a fungating lesion appeared on the cheek above the margin of the flap but not invading it. (Fig. 15.) This was widely resected and replaced with a temporal artery flap from the scalp. (Fig. 16.) Microscopic sections showed squamous cell carcinoma. Ten years after the last operative procedure the patient was free from evidence of recurrence. (Fig. 17.) It is interesting to note that the skin flaps have in the meantime been extensively invaded by the lupus.

CASE XI. *Squamous cell carcinoma in irradiated keloids of both forearms:* The patient, a male sixty-three years old, had been severely burned eighteen years prior to our first observation. No skin grafts were done and he developed marked keloids and contracted scars involving the flexor aspects of both forearms and wrists. He was given an extensive course of x-irradiation to the keloids up to about six years prior to our observation. At the time of examination he showed flexion contractures of both wrists and large areas of irregular ulceration involving the flexor aspects of both forearms. (Fig. 18.) Biopsies showed both to contain well differentiated squamous cell carcinoma. The area on the right forearm was resected and replaced with a two-stage, broad-based abdominal flap. Because the flexor muscles and tendon sheaths of the left forearm were extensively involved with carcinoma it was necessary to amputate this arm. Bilateral axillary dissections were performed but no lymph nodes were involved by carcinoma. Five years later the patient was free from evidence of recurrence.

Comment. While free grafts are occasionally practical for replacement of irradiated skin which is the seat of an early carcinoma, pedicle grafts of full thickness skin and sub-

FIG. 15. Case X. Fungating recurrence in cheek adjacent to the flap margin two years after original resection.

Fig. 16. Case x. Appearance after resection of recurrence shown in Figure 15, and replacement of skin by means of a temporal artery scalp flap.

cutaneous tissue are usually more practical and probably safer in the long run. The author has been impressed on several occasions with the apparent resistance of flaps from other regions to recurrent cutaneous carcinoma. It seems likely that they are seldom if ever invaded by carcinoma. It is also an advantage at times to bring in a blood supply from a neighboring region to stimulate collateral circulation in the poorly vascularized bed. In this respect temporal artery flaps are particularly useful.

The prognosis of irradiation carcinoma of the skin should not be regarded as too serious, as illustrated by several cases reported. Radical surgical removal and replacement of skin provides protection for a period of years in most instances and when recurrences are encountered they still may be arrested or cured if treated as radically as the initial lesion.

It has been contended by many experienced surgeons that no attempts should be made to replace the skin resected because of malignancy at the time of the primary operation. Esthetic and economic conditions have often made it seem expedient to replace the damaged skin immediately with some type of graft and cure rates have not apparently been unfavorably influenced thereby.

Fig. 17. Case x. Appearance of the patient twelve years after initial resection. At the age of seventy-nine he is free from evident recurrence in spite of the fact that the lesion shown in Figure 14 had already invaded the deep cervical lymph nodes.

FIG. 18. Case XI. Squamous cell carcinoma of both forearms following irradiation of burn keloids. The area on the right forearm was resected and replaced with a broad-based abdominal flap. The left arm was amputated because the neoplasm had invaded the flexor muscles and tendons of the forearm. He remained free from recurrence five years after operation.

SUMMARY

The various types of skin injury following roentgen ray or radium treatment for a variety of conditions are reported. The resulting unfortunate sequelae range from acute burns to malignancy.

Illustrative case reports are given, together with the pathologic findings and the plastic repair.

Worthy of note are the long interval between the original treatment and the development of malignant change and the types of carcinoma found at operation.

A report of the unfavorable results of irradiation which inevitably seek out the plastic surgeon should not discourage the use of this powerful agency under proper conditions and for proper indications. It is suggested, however, that its use in the treatment of benign conditions which can be handled effectively by other means might be curtailed.

TRACTION SPLINT FOR HAND AND FINGERS

DONALD GORDON, M.D.
New York, New York

IN 1924, a young man was sent to me with comminuted fractures of the second, third, fourth and fifth metacarpal bones of the right hand. The second was compounded on the dorsum of the hand where there was a granulating wound 2 inches long. The patient received his injuries several days before, as I recall it, in a fall from an oil derrick in a western oil field. The wound had been treated and left open but little attempt at splinting had been made.

His history had been lost but his x-ray films were preserved and are reproduced in this paper. He was a graduate of Annapolis with a promising future and I felt keenly the responsibility of restoring his right hand to as good a function as might be attained.

I was impressed at that time and still am with the inadequate degree of traction which is manifested by the relatively short elastic bands used in the different types of so-called banjo splints, for the following reason: When any form of traction using a weight or a weight acting over a pulley is used, the pull is constantly of the same degree. This does not occur when elastic traction is used. If the material used to institute traction is short, it is obvious that any small degree of shortening between its two ends will effect the efficiency of the pull. The reason is that with any given elastic material the elongation is proportional to the tension applied, provided the elastic limit is not exceeded, or for any given elastic device the greater the possible elongation the greater is the back and forth motion without loss of effective tension. Stated in another way, the range of motion throughout at which effective tension can be maintained is directly proportional to the length of the elastic member. With these facts in mind the short elastic bands used in the so-called banjo splints have always seemed to me to be lacking in efficiency. The turnbuckle devices seen on some of these would appear to bear out this impression.

I devised this splint and applied it with skin traction using a technic from which I have not departed nor found wanting. Variations of it will be mentioned later. The materials used were a 3/16 inch basswood splint, a piece of 1/8 inch Bessemer steel rod, four small brass pulley shives with central holes fitting easily over the Bessemer steel rod and four brass springs used for hanging curtains (bought in the five and ten cent store). The pieces of wire used were cut from ordinary 2 inch brass safety pins.

The splint is constructed as follows: The splint wood is cut roughly to fit the forearm with its distal end shaped as in Figure 1. The lateral edges of this distal portion are cut out and a shallow groove cut in the two edges leaving the shoulder at the proximal end for the ends of the rod to butt against. The required number of shives are threaded onto the rod, one for each finger to be put in traction. The rod is bent with sharp angles to avoid the shives jamming on the curves. The length of the side pieces of the rod should be measured from the shoulder in the proximal end of the grooved edge to 5 inches or more beyond the end of the wood splint. One must allow enough room between the ends of the fingers when in traction and the pulley shives to avoid them touching and preventing traction. The bent rod is attached to the wood splint by laying its ends in the grooves butting against the shoulders cut to receive them. These are then held in place by winding two or three layers of wide adhesive plaster about this end of the splint and rod ends. The rectangular distal end of the splint is used to build up a support to preserve the palmar arches and curve of the hand. Traction is secured by gluing strips of muslin with Ambroid Canoe glue* on the indicated fingers. A strip of muslin is cut wide enough to extend a little less than half around the finger and a little longer than the combined length of the area to be used for traction on the dorsal and volar surfaces of the fingers. The edges of the strip should not be so wide as to meet and completely surround the fingers in order to allow for swelling. This may extend up onto the hand in metacarpal injuries. A small longitudinal slit is cut in the center of the muslin strip half

* Ambroid Canoe glue can be obtained at any hardware store.

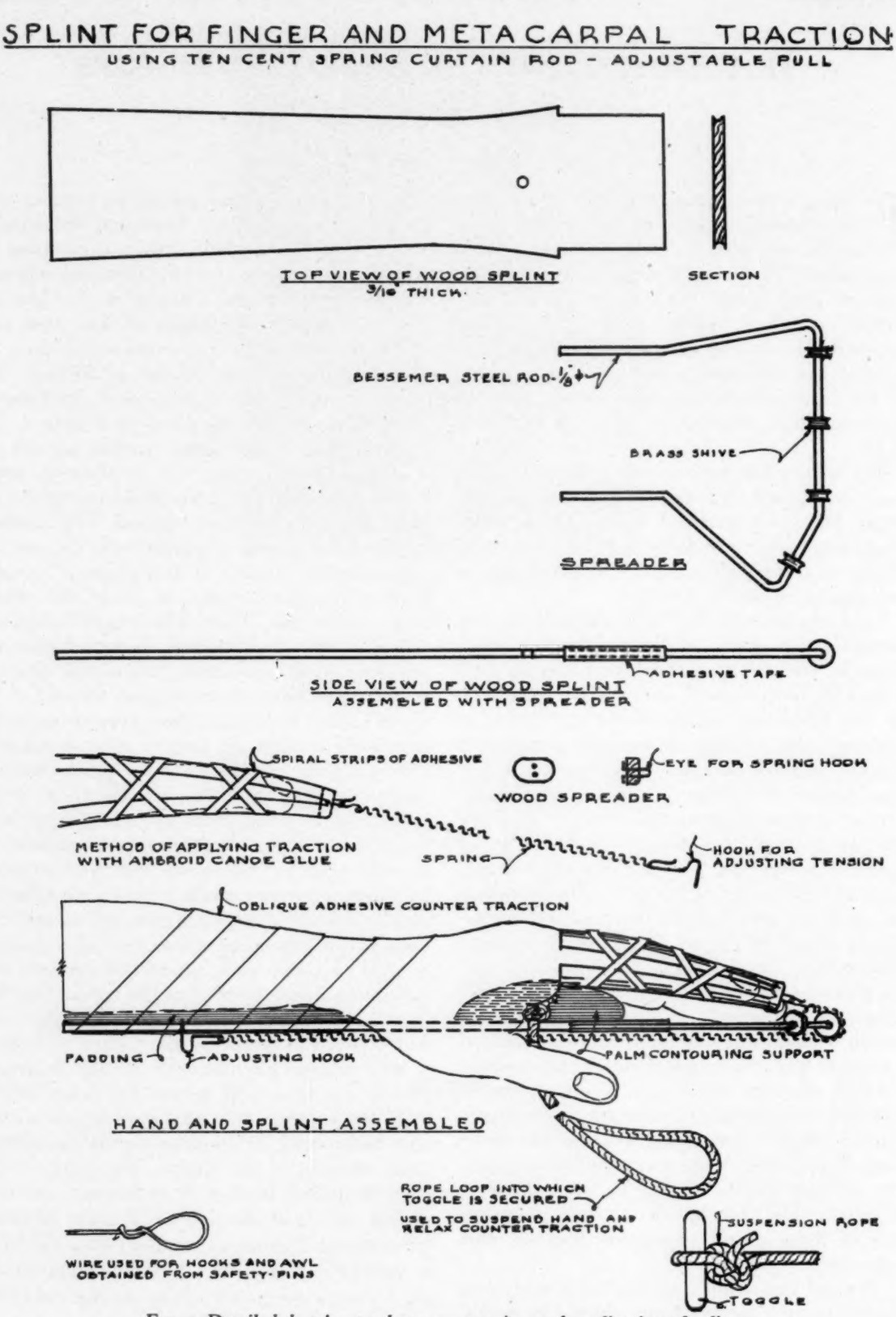


FIG. 1. Detailed drawing to show construction and application of splint.

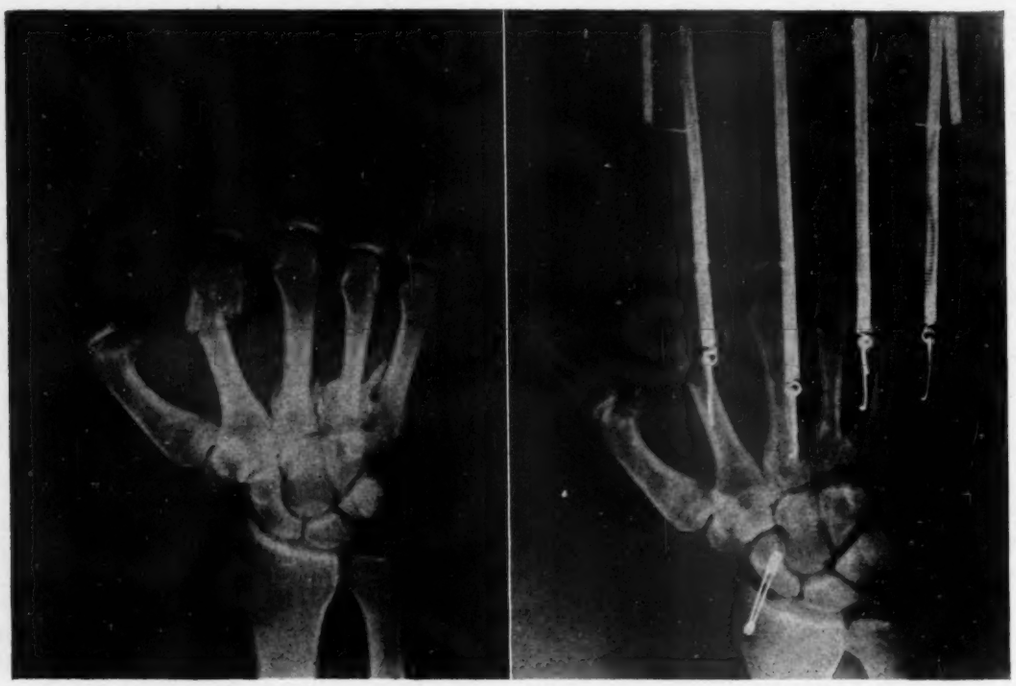
way between its two ends to receive the small wire loop of the specially shaped spreader. The strips are then placed on a piece of paper and the glue spread quickly on each piece just before the strip is applied. The spreader is placed in position and the strip applied to the dorsum and volar surface of the finger which is immediately bandaged with a few turns of a gauze finger bandage for a good contact of the glue. This bandage is cut off as soon as the glue dries which will be well set in half an hour. Each strip should be applied separately as the glue dries quickly. When the requisite number of fingers have been prepared, the forearm is shaved of hair and the surface of the splint is well padded with cotton batting or wadding, *not with sheet wadding*. This is laid on the splint but not bandaged on.

The splint is then applied to the anterior surface of the forearm with the distal end of the wood reaching to the middle of the proximal phalanx at the interdigital web. The splint is held to the forearm with adhesive plaster strips 1½ inches wide overlapping each other, and extending from wrist to the upper end of the splint where the tape is passed over the splint's end to prevent it slipping upward when supporting countertraction. These adhesive strips are put on obliquely extending from the splint downward and posteriorly. This is absolutely necessary, as at night when the hand is hung up by the device arranged for doing so, the obliquity of the strips become less so as the splint is pulled upon, and lymphatic return and circulation is not interfered with by a constrictive dressing. One complete turn of the spring coil at one end of the long spring is opened up with pliers to form a hook which is hooked into the wire loop in the spreader. The traction spring is then brought over the pulley shive and measured upon the undersurface of the splint to about its middle. It is then cut off with pliers and a couple of loops turned down to engage the hook which is used to lock it to the splint. A longitudinal line of holes is made from this point with a small awl shown in Figure 1 constructed from the same safety pin wire as the hook, a ¼ to ½ inch apart extending upward and downward. Tension on the spring is made by placing the free arm of the hook in such a hole as will afford the desired degree of traction. This hook can be and should be put on the maximum tension at first. The surgeon or the patient under his direction can change the degree of tension from time to time as might be indicated.

It is well to call attention here to the fact that a given area of skin will tolerate only a certain amount of pull. Ambroid glue will not slip or irritate the skin, but if a tension is made in excess of the tolerance of the skin area used, blebs will appear at the proximal end of the traction strips or near an extensive fracture of the metacarpals. Excessive pull may determine blebing. These blebs are best treated by a double or triple strength calamine lotion (without carbolic) and diminishing the degree of traction by changing the position of the hook.

An important feature will be noted in Figure 1. In the wood splint there is a hole which should come under the concavity of the palm. I pass the end of a piece of hatter's cord or a line strong enough to support the weight of the upper limb off the bed when the patient is resting in bed, and tie a big knot in the end so that it will not pull out of the hole. On the free end a loop is tied about three inches long, and this line should be long enough to have this loop and knot extend beyond the pulley shives. The purpose of this arrangement is, that when the patient is in bed at night a stout line is tied to a picture hook which is hooked on the moulding or tied to an elevated object; the lower free end of the line has a small piece of wood tied to its middle. The line is of such a length that when the loop is passed over the wooden toggle and is supported by this line, the elbow is off the bed. This puts a pull on the whole traction and releases the constriction of the adhesive encircling the forearm and definitely increases the degree of traction, which must be kept in mind. This elevation and relief of constriction at night has a most definite effect in lessening the degree of swelling acquired in the day time and diminishes the tendency of periarticular fibrosis about the finger joints.

To preserve the concave palmar arches, I have used felt pads in cold weather, and in hot weather a flattened roll of copper fly screen, the edges of which are taped with adhesive plaster. I use a simple gauze bandage loosely applied to cover all. My patients have used lengths of stocking with holes cut for the thumb or such fingers as are not in traction to permit functioning. I like to apply traction to a less degree on additional fingers lateral or on both sides of the injured one to preserve the alignment and for clinical checking.



2 3

FIG. 2. Film showing anteroposterior view of hand before traction.
FIG. 3. Film showing anteroposterior view of hand with traction.

After the gauze bandage, which is put on to ensure good glue contact, has been cut off, I apply narrow adhesive strips in a long spiral up the fingers to maintain contact of the edges of the traction strips.

The wood splint and wire extension can be designed for traction of two or more fingers, allowing limited use of the free fingers and thumb. In the illustration, I have shown how the thumb can be held in abduction by the pulley arrangement. To prevent the pulleys from sliding laterally from a desired position, small bushings can be built up on each side of them with narrow adhesive strips.

The spreader is shaped from a portion of the same wood as is used in the splint. Its oval shape prevents lifting the traction strips from the end of the finger and especially compressing the finger tip with its resulting discomfort. Its contour should roughly coincide with a cross section of the finger at about ¼ inch from the tip. The two holes are drilled with a drill made from the safety pin wire. A U-shaped piece of the wire is put through these and the ends turned over leaving the loop as shown, which is placed through the opening cut in the traction strip before applying, and to which the hook on the end of the spring is attached. The adjusting hooks on which the traction depends must be made so that the right angle portion which enters the wood must fit the hole snugly and be at a correct right angle, otherwise the hooks will pull out. They should not be long enough to extend so far through the splint as to penetrate the padding. To hold the hooks in place, a piece of adhesive laid over them and extending up on the sides will prevent their slipping out. Soaping the awl will facilitate penetrating the adhesive.

If blebs form at the proximal end of the traction strips, usually on the dorsum, the strip end can be lifted by using acetone on a pledget of cotton and by removing the end for a short distance to determine the extent of the blister, then Calamine may be applied. The strips can be extended proximally onto the palm and dorsum of the hand.

Although it takes time to make and apply this splint, it is the most efficient ambulatory finger and metacarpal traction device I know of. One is well repaid for the time taken to make and apply it for the comfort it affords the patient and the satisfactory result. The thing I would emphasize about the splint is the efficiency of a long spring or elastic traction member and the simplicity of adjusting the same. The springs I bought in 1918 and until

4 5

Fig. 4. Film showing lateral view of hand before traction.
Fig. 5. Film showing lateral view of hand with traction.

the war were not as stiff as the one's I have been able to secure since the war.

I have made a splint substituting sheet aluminum for the wooden portion, but I have not used it as it does not readily lend itself to traction to less than four fingers.

I have not felt the need of using a plaster cast about the forearm. It has obvious difficulties in affixing the bar supporting pulleys and in arranging for tension hooks. However, such arrangement is not precluded.

For traction with the fingers flexed, a cross bar under the palmar portion would be called for to pass the spring over to make the direction of the spring conform to the angle created by bending the shive supporting member. If enough traction cannot be supported by the skin area for fractures of proximal and middle phalanges, threaded wires can be used in the terminal phalanx with a suitable tractor loop. The threads prevent side slipping of the wire in the bone and on the loop hooks.

DIAGNOSIS OF CLOSTRIDIAL MYOSITIS*

KENNETH F. LOWRY, M.D. AND GEORGE M. CURTIS, M.D.
Columbus, Obio

MANY of our greatest advancements in surgery have had their inception in the experimental laboratory, while others have been achieved through astute clinical observations. Anaerobic gas infection has benefited from both endeavors.

Although recognized as a distinct surgical entity prior to World War I, its high incidence[1] on the Western Front provided an unusual opportunity for clinical observations and study, which contributed much to our understanding of this infection.

In the years which intervened between World War I and World War II, further experimental and clinical investigation aided considerably in crystallizing our knowledge of clostridial infections. However, through all of this, one outstanding error in our concept persisted: Most of us continued to regard all suspiciously infected wounds, from which clostridia were recovered as incipient or established gas gangrene. Furthermore, if in addition to the finding of clostridia, clinical gas production was apparent, and a foul putrefactive odor was detected, we were positive that gas gangrene was present. In other words, we failed to recognize first, that clostridial organisms may be frequently recovered from infected or even clinically clean traumatic wounds, yet, seldom interfere with normal wound repair;[2] and secondly, that a foul smelling wound with extensive gas in the subcutaneous and fascial planes is most often not true "*gas gangrene*," but its relatively benign cousin "*anaerobic cellulitis*."

The recent war again provided us a golden opportunity to extend our knowledge in clostridial infections. Despite this improved knowledge considerable confusion still exists as to just what constitutes a *clostridial myositis* and what constitutes an *anaerobic cellulitis*. The fallacy of statistics regarding pathology, prognosis and methods of treatment when we have failed to recognize, and differentiate these two clostridial infections is at once appreciated. The latter calls for thorough yet conservative treatment, whereas clostridial myositis demands prompt, energetic and radical treatment.

DEFINITION

Clostridial myositis (gas gangrene) is clinically a very rapid, invasive involvement of muscle, associated with severe toxemia, moderate fever, rapid pulse, apprehension, delirium, a rapidly developing anemia and a reduced blood volume. Localized pain is often the first symptom, but frequently a sense of heaviness in the involved extremity, or a rise in the pulse rate, with a slight increase in temperature, will give a clue to the presence of infection before pain is mentioned.

Anaerobic cellulitis or fasciitis (gas abscess), on the other hand is a relatively benign clostridial infection, which, however, more clearly fulfills our preconceived ideas of "gas gangrene" than does true clostridial myositis itself. This is due mainly to the almost constant presence of gas, crepitation and foul acrid discharge, which we have always considered synonymous with "gas gangrene." This infection involves the subcutaneous tissues and the fascia between the muscle groups but *never* the muscle bundles, except those which have been traumatized in the immediate vicinity of the wound. Toxemia, with mental symptoms, hypotension and anemia are conspicuously absent, unless due to the associated injury. Severe localized pain is almost never a symptom.

Anaerobic streptococcal myositis is very rarely encountered. Its onset is insidious and is associated with swelling, edema and discoloration around the site of injury, which extends diffusely.[3,4,5] As this increases, pain begins and becomes rapidly severe. The pulse and temperature may be quite high and associated with a mild delirium. Locally, the wound is wet, foul smelling, discharging a profuse thin, blood stained seropurulent material. The muscle involvement is focal rather than diffuse. Early, circumscribed areas of firm, pale muscle have been noted[6] which later became whitish-gray, then began to liquefy, coalesce and form a small amount of gas.

Treatment of this infection must be prompt and energetic. Relaxing incisions, including

* From the Department of Research Surgery, Ohio State University, Columbus, Ohio.

wide resection of all involved muscle and connective tissue with adequate drainage is mandatory.

ETIOLOGY

It is now an established fact that many traumatic wounds (50 to 60 per cent) may be contaminated with Clostridia[7] yet only a very small percentage of these wounds (1 to 2 per cent) ever show any clinical evidence of a clostridial infection. Therefore other factors, in addition to the presence of these anaerobes, are usually present before a clinical anaerobic infection will develop. In general, one may state that the presence of clostridial organisms, plus excessively damaged necrotic, or avascular tissue, particularly muscle and blood clot, appears to be essential for the development of clostridial myositis. Just why only a small percentage of the wounds in which these conditions exist, develop anaerobic infections is not entirely clear. Our experience in the recent war, however, has established certain facts of etiologic importance, which very definitely favor the development of a clostridial myositis.

These etiologic factors in the probable order of their importance are: (1) major vascular injury; (2) compound fractures; (3) prolonged time interval between wounding and treatment; (4) wounds contaminated with manured soil; (5) thigh and buttock wounds; (6) severe wounds, with marked tissue destruction, and (7) wounds contaminated with woolen clothing. There are numerous other less specific etiologic factors which might be considered, such as the state of nutrition at the time of wounding, the amount of associated hemorrhage, with prolonged shock and reduced blood volume, and the weather, which if cold, may have contributed to prolonged chilling, ischemia and anoxia of all body tissues.

It should be emphasized that these etiologic factors which we have enumerated are not hypothetical figments of imagination, but are real, definite, absolute factors, established by statistical experience. Thus Power[8] and North[9] have stressed the almost certainty of gas gangrene developing in devascularized muscle contaminated with Clostridia. Of 108 amputations which we, of the 2nd Auxiliary Surgical Group, did because of an anaerobic infection, there were only eleven in which vascular injury was not present.[10] Furthermore, it has been stated[6,11,12] that 60 to 75 per cent of clostridial infections are associated with compound fractures; yet based on final statistics of World War I,[13] compound fractures are present only in approximately one-sixth or 17 per cent of the total number of battle casualties.

In our opinion a constant awareness of these established etiologic factors is essential to an early diagnosis.

DIAGNOSIS

It appears pertinent that we again re-emphasize that the mere detection of Clostridia in a wound is not of great significance. It has long been known that these organisms may be present without giving rise to clinically recognizable infection.[2]

The rapid identification technic recently proposed by Butler[14] in Clostridium welchii infections offers hope that the problem of diagnosis may be much simplified. The degree of capsulation of the organisms, together with the extent of damage to leukocytes, as revealed in specially stained direct smears, provides her with a reliable index of the severity of the infection. Thus, heavy capsulation, with damage to leukocytes, points to an actively invasive infection (clostridial myositis). Conversely, poor capsulation, active phagocytosis and lack of leukocyte damage, all indicate that a severe invasive infection is unlikely. These observations certainly warrant further study.

In our experience the diagnosis of *clostridial myositis* was definitely *clinical* and not *bacteriological.*

The necessity of relying almost exclusively upon clinical appraisal prompted us to establish some diagnostic criteria. Although quite elastic, and certainly when considered individually—not infallible—these criteria were found quite helpful, not only in establishing the diagnosis of a clostridial infection but also in making a clear cut differential diagnosis. (Table I.) These criteria in the probable order of their significance are as follows:

1. *Toxemia.* This is one of the most prominent and constant features in *clostridial myositis.* The mental symptoms in the early case may be manifested only by a bright-eyed alertness or overanxiety for personal welfare. In the more advanced or fulminating infection, the patient may be quite euphoric and excitable, or there may be apathy, drowsiness and delirium. In *anaerobic cellulitis* toxemia is conspicuous by its

absence and thereby constitutes one of our most important points of differentiation.

2. *Pain.* This is often very severe at the site of injury. One might expect that these patients, with severe complicated wounds, should have considerable pain. But, such is not the case, especially if their injury is immobilized. Therefore, the development of severe pain at the site of injury is a most significant symptom. Occasionally, patients may complain of a sense of weight, heaviness or lightness in the wounded extremity before the onset of pain. In *anaerobic cellulitis*, pain is usually absent, but if present, is mild in character.

3. *High Pulse Rate.* A pulse rate, usually over 120, and out of proportion to the degree of infection or temperature is usually present. As the infection increases, the pulse rate becomes more rapid and of poor quality. In *anaerobic cellulitis*, the pulse rate may be elevated, but it generally follows the temperature curve, and is of good quality.

4. *Anemia.* This condition is almost always present and varies with the length of the infection and the degree of toxemia. It is not unusual to encounter total red cell counts under 1.5 to 2 million. This anemia is said[15] to be due to the enzyme lecithinase, present in the alpha toxin of Clostridium welchii, which rapidly breaks down the outer lipid membranes of erthrocytes and other cells, causing hemolysis and cell destruction. Anemia is not a characteristic finding in *anaerobic cellulitis*.

5. *Hypotension.* The exact mechanism of this rather constant finding is not too well understood. However, since shock and reduced circulating blood volume[15] are intimately associated with the toxemia of *clostridial myositis*, we may assume that the hypotension is a measure of the degree of shock and oligemia present. In *anaerobic cellulitis* we have never noted hypotension, shock or an alarming oligemia.

6. *Temperature Elevation.* The significance of this lies in the fact that it is rarely over 100° to 102° F., whereas the extent of the infection, and the rapid pulse rate, indicate that the temperature should be much higher. In *anaerobic cellulitis*, the temperature may vary from 101° to 103°F. It closely parallels the pulse rate and degree of sepsis present.

7. *Wound.* Ordinarily, *clostridial myositis* is not a single bacterial infection, but a combination of several Clostridia with Clostridium welchii predominating. Examination of the wound early in the infection may reveal only a slight edema associated with a thin, watery discharge. Rather extreme tenderness is usually present. Gas is never a prominent feature and at this stage is often absent. In a similar wound, a few hours later the edema will be more marked, there will be more discharge and possibly a few bubbles of gas may be expressed on pressure.

Unfortunately, the infection is often much more advanced before it is seen by the surgeon. Then, the extremity may be found swollen, livid or mottled, and as a rule, quite painful. There may be a profuse serous or serosanguine-

TABLE I

ANAEROBIC GAS INFECTIONS—DIAGNOSTIC CRITERIA

	Clostridial Myositis	Anaerobic Cellulitis—Fasciitis	Anaerobic Strep. Myositis
Toxemia	Constant	Absent	Mild, varies with temperature
Pain	Often present, severe	Absent	Often present, severe
Pulse	High—poor quality	Proportionate to temperature; good quality	High—proportionate to temperature
Anemia	Usually present	Absent	Not characteristic
Blood pressure	Low	Normal	Normal
Temperature	100° to 102°F.	101° to 103°F.	High
Wound			
(1) Discharge	Varies—slight watery to profuse brown	Profuse, brownish seropurulent	Wet, edematous, profuse, blood-stained, seropurulent
(2) Odor	Inconstant	Constant, foul putrefactive	Foul
(3) Crepitation	Inconstant	Constant, extensive	Slight, late
(4) Muscle	*Always* involved—diffuse	*Never* involved—except adjacent to wound	Usually involved but *focal*

ous discharge from the wound which has saturated the dressing. This may have a peculiar sweetish odor or it may be pungent, foul and putrefactive. Still later, the discharge may turn into a dirty brown color. On the other hand, there may be virtually no discharge; and if muscle is exposed, it may appear dry and dull. Some surgeons insist that there is a characteristic odor to gas gangrene which is quite diagnostic. In our experience neither the odor of the wound or crepitation have been reliable signs.

However, it is the local appearance of the involved muscle, which is the most constant and characteristic feature of *clostridial myositis*. This may vary from a salmon pink or brick red to a dirty, gray slate color, and in extreme cases[16] it will appear black and diffluent. Should any doubt exist as to their involvement, it is well to keep in mind that clostridial infected muscle does not contract or bleed when cut.

Let us now summarize for the sake of simplicity this discussion on the wound as follows: (1) *Discharge* may vary from a slight watery or dirty brown to very profuse and serosanguineous; (2) odor is inconstant, varies with the secondary wound invaders. If present, it is usually putrid or decayed meat in character; (3) crepitation is not a reliable sign; it is often absent until late in the infection. If present, it may be detected by varying pressure with a stethoscope before it can be palpated with the fingers.

The local findings in *anaerobic cellulitis* are so characteristic that a differential diagnosis may be made without difficulty. MacLennan[3] describes it as a dirty wound, with a foul odor and a moderately profuse, brownish seropurulent discharge. Jergesen[6] has noted that not infrequently the wound is lined with a shaggy-grayish-white diptheritic membrane, which when cut away reveals normal, healthy, bleeding, contractile muscles. Gas is *always* present and abundant. It is found involving and extending diffusely in the fascia between muscle groups, crackling in the subcutaneous tissue and bubbling up through the foul, putrid wound discharge. Thus its presence, when extensive, and in the absence of a pronounced toxemia is very important in differential diagnosis.

The treatment of anaerobic cellulitis while conservative should nevertheless be prompt. It is essentially surgical, consisting of relief of tension, excision of necrotic and grossly infected tissue and the establishment of adequate drainage.

With these criteria, as well as our etiologic factors in mind, a diagnosis of *clostridial myositis* may be conveniently developed around two general groups: (1) Infection anticipated, beginning or established in the untreated wound, and (2) infection developing in the postoperative or débrided wound.

Especially in group 1, the importance of a careful history in developing a diagnosis cannot be overemphasized. The "time lag" is particularly important. The potentialities of a contaminated wound incurred in a barnyard as against one incurred on a paved highway are considered. A history of previous hemorrhage, necessitating the prolonged application of a tourniquet, a mental note of the type and soiled condition of the patients' clothing, the location of the wound, and the presence of an associated vascular injury or compound fracture, all contrubute to our local and general evaluation of anticipated findings.

An evaluation of these potential etiologic factors when added to a carefully applied analysis of our diagnostic criteria, place in our possession, maximum presumptive evidence, either for or against a *clostridial myositis*, even before we have inspected the wound. This is not a drawn out, time consuming procedure; with the possible exception of the blood count, it can all be accomplished within a few minutes while resuscitative measures are being initiated. If the diagnosis is reasonably certain, wound inspection may be deferred until the patient is under anesthesia on the operating table. This has been our usual policy. However, if any doubt exists, a definite diagnosis can be made in most instances after inspection.

X-rays can be of definite diagnostic value in this infection. Occasionally, in a penetrating wound with a small wound of entrance, the first indication of a *clostridial myositis* will be the finding of a few bubbles of gas in the region of the foreign body on the x-ray film. In general, however, the finding of gas in the soft tissues should be accepted with reservations. Gas bubbles are not only present in an anaerobic cellulitis[11] but the nature of the wound occasionally allows air to enter its depths. Muscle fibers, which are cut suddenly by a sharp fragment, will spring apart, and may aspirate air through the skin wound into the gap.[16] In the absence of one or more of our diagnostic criteria, either of the latter two conditions should be considered.

Group 2 infections (occurring in a débrided

wound) are most unfortunate and should not occur, but they do and with distressing frequency. We must remember, however, that débridement is not the ideally aseptic excision *en masse* procedure, which is employed in removing a malignant growth. Débridement is an operation of *incision* and *excision* in which the surgery is accomplished almost entirely from within a potentially contaminated if not already infected tract. Furthermore, many wounds, because of their proximity to vital structures, such as major nerves and blood vessels, do not lend themselves well to a *complete* débridement. It is, therefore, inescapable that some organisms, a small blood clot, or a piece of devitalized muscle may, in some instances be left behind.

Thus, with the knowledge that *clostridial myositis* may develop in spite of prophylactic débridement, chemotherapy and antitoxin, an attitude of observant alertness should be adopted by everyone who has contact with these postoperative patients. The onset of this infection is characteristically acute and fulminating, the toxemia severe and rapidly progressive.

If etiologic factors favor a high expected incidence of anaerobic infections, it should be highly desirable for the surgeon to instruct his day and night nurses and ward attendants in the practical application of our formulated diagnostic criteria. Thus the busy surgeon's attention might be directed to an infection in its incipiency. An increase in the pulse rate, out of proportion to the temperature, is an indication for investigation. The development of local pain or undue apprehension should require the surgeon's attention and not be relieved with a blanket order for another hypodermic, by an overly busy, or too sympathetic nurse. We trust that the alert surgeon will never wait for the "odor" or the development of edema and crepitation, outside the limits of the dressing.

CONCLUSION

In conclusion we wish to direct attention to several points:

1. Our experience indicates that clostridial infections fall into three separate and distinct clinical types, depending upon the inherent invasive characteristics of the clostridial organisms responsible for the infection. First, that type of *clostridial myositis* or true gas gangrene, which is so highly invasive, that it will attack, invade and destroy undamaged tissue. This type is not common. Second, that type of clostridial myositis, which is less invasive, but does spread in devascularized and traumatized muscle. It is usually localized to one muscle or muscle group, and is attended with less shock and toxemia than the first type. However, if neglected, the action of its toxins on adjacent tissue, will be sufficient to permit spread in previously healthy muscle. Third, anaerobic cellulitis or fasciitis, the characteristics of which we have previously mentioned.

2. Although clostridial infection is generally regarded as a complication associated with the trauma of war, it is also a complication which occurs too frequently in civilian wounds.

3. It is apparent that we have been leaning too heavily on chemotherapy, to compensate for needless time lags and incomplete, minimal débridements.

4. The diagnosis of clostridial infection at present is definitely clinical and not bacteriological. Many contaminated wounds contain Clostridia, yet experience has shown that in very few of these, a recognizable clostridial infection develops.

5. The importance of differentiating between a *clostridial myositis*, or true "gas gangrene" and an anaerobic cellulitis, or fasciitis, cannot be over stressed. The fallacy of statistics regarding pathology, prognosis, mortality and methods of treatment, when we have failed to recognize and differentiate these two clostridial infections, is at once appreciated.

SUMMARY

1. Certain etiologic factors have been established, which if constantly borne in mind, will make the surgeon so alert to an impending clostridial infection, that early diagnosis and prompt energetic treatment will be accomplished before the infection has had an opportunity to become firmly established.

2. These etiological factors, which favor clostridial infection are: (1) major vascular injury; (2) compound fractures; (3) prolonged time lag; (4) wounds contaminated with manured soil; (5) thigh and buttock wounds; (6) wounds with marked tissue destruction and (7) wounds contaminated with woolen clothing.

3. Certain diagnostic criteria have been established which will not only aid in establishing a diagnosis of clostridial myositis, but will also

aid in differentiating it from the relatively benign clostridial infection anaerobic cellulitis.

4. These criteria are: (1) toxemia or shock or both; (2) pain at the site of injury; (3) high pulse rate, out of proportion to the temperature; (4) anemia (1.5 to 2 million); (5) hypotension; (6) moderate temperature, 100° to 102°F. and (7) muscle involvement, which does not bleed or contract when cut. The discharge, odor and crepitation are inconstant and unreliable signs in clostridial myositis.

Although the recent war has provided an opportunity for an improved knowledge of these infections, the problem has not as yet been satisfactorily solved. It is our earnest hope that laboratory and clinical investigation will be relentlessly continued, so that in the event of another war, we may better cope with this deadly complication of traumatic wounds.

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REPAIR OF MAJOR TENDON RUPTURES BY BURIED REMOVABLE SUTURE*

HARRISON L. MCLAUGHLIN, M.D.

Assistant Professor of Clinical Orthopedic Surgery, College of Physicians and Surgeons, Columbia University

New York, New York

ALL large tendon ruptures are difficult surgical problems. The rupture takes place through unhealthy, degenerated and avascular tendon tissues. In the process of rupturing these tissues become extensively shredded and lacerated so that clean cut, viable fragment ends suitable for primary suture, such as may be expected in an incised wound through a tendon, are not present. The extent of the injury to the tendon and its associated structures as well as the accompanying local tissue reaction is severe. The associated muscle components are among the strongest in the body so that marked retraction of the proximal tendon fragment is the rule and these muscle forces must be overcome and controlled before restoration and maintenance of anatomy can be accomplished. When the lesion is of weeks' or months' duration, as is not infrequently the case, extensive cicatrization of the whole local area and a relatively fixed contracture of the retracting musculature makes the treatment problem still more difficult. In all cases, even after surgical repair has been accomplished successfully, the normal functional demand which ambulation places upon the major tendons of the lower extremity has made maintenance of function throughout the healing period difficult to accomplish without seriously jeopardizing the integrity of the suture line.

It has been common practice in repairing large tendon ruptures to pull the retracted proximal fragment as far distalward as possible and to bring the distal fragment as far proximally as it would come by some combination of manual traction and posture of the injured extremity. By this mechanism, and utilizing all of the shredded and lacerated tendon ends for suture purposes some sort of repair usually was accomplished. A surgically satisfactory repair rarely, if ever, was obtained. More often than not the suture line was precarious enough so that reinforcement and bridging of the imperfectly closed gap between the fragment ends by a free fascial graft or some heavy suture material was required before the repair would hold. Postoperative immobilization usually was mandatory. Often, especially following repair of the tendo achillis, it was necessary to apply the immobilization in the poorest possible functional position. Continued function of the extremity during the healing period rarely was possible and the penalties of disuse and immobilization were inevitable and severe.

This treatment program has produced results that left much to be desired. The absence of any well documented end result reports in the literature suggests that most surgeons have not enjoyed conspicuous success in repairing these lesions. Logical evaluation of the problem in the light of basic surgical principles and the known physiology of tissue healing makes it clear that the best results cannot be expected following any such regimen which violates every principle of surgical repair and the management of damaged motor-skeletal structures. The optimum result following tendon repair requires accurate and snug apposition of healthy to healthy tissue without tension at the repair site, with a minimum of foreign material (whether suture material, fascia or dead tendon fibers) at the healing site and a maximum maintenance of function throughout the healing period. Major tendon repair has in the past been characterized by inaccurate and incomplete apposition of avascular and degenerated tendon ends under considerable tension by means of many sutures, various forms of reinforcement and a postoperative program which abolished function throughout the healing period. Therapy of this type is irreconcilable with good results.

It has been pointed out in a previous report[2] that accurate and snug apposition of healthy to healthy tendon tissue with a minimum of

* From the Fracture Service of the Presbyterian Hospital and the Department of Orthopedic Surgery, College of Physicians and Surgeons, Columbia University, New York, N. Y.

tension on the repair and a minimum of foreign material in the healing site can be most nearly accomplished by means of the ingenious removable traction suture evolved by Bunnell[1] for the management of tendon injuries in the hand. His contention that the removable suture principle was applicable to the repair of other tendons suggested a method for improving the results in major tendon lesions and stimulated development of the technic to be described. Some modifications of his technic were necessary. The presence of wires emerging through the skin coincident with motion of the part over a period of weeks would constitute a constant potential risk of infection. The retractile force of the muscles to be neutralized is many times greater in the major tendons than in the hand so that the countertraction required greatly exceeds that which can be provided by a button on the surface of the skin. Bunnell's technic, therefore, has been modified so that complete skin coverage of the entire fixation apparatus and a solid bony structure rather than a button on the skin for anchorage of the main traction suture are provided.

TECHNIC

Repair of the Tendo Achillis. 1. A posterior midline incision over the distal one-half of the lower leg, curving laterally at a point 2 cm. proximal to the os calcis to proceed distalward over the lateral surface of this bone to within 2 cm. from the plantar surface of the foot, (Fig. 1C). Lateral curvature of the lower portion of the incision is important for two reasons: (1) The lateral surface of the os calcis requires exposure; (2) posterior midline shoe pressure upon the operative scar is avoided.

2. The ruptured tendon is exposed and the sheath incised in the midline from the level of the musculotendinous junction to the os calcis.

3. The degenerated and lacerated end of each tendon fragment is débrided back to healthy tendon tissue. (Fig. 1A, 1.)

4. A small area on the lateral surface of the os calcis is exposed, (Fig. 1A, 2.)

5. A drill is passed through the os calcis from lateral to medial. As it elevates the skin on the medial side of the heel a small stab wound is made. (Fig. 1A, 3.)

6. As the drill is withdrawn a long screw is passed through the hole from medial to lateral. The head end of the screw is left projecting a short distance through the medial stab wound. (Fig. 1B.)

7. A mattress suture of stainless steel wire is placed in the proximal tendon fragment in such a way that (1) the horizontal portion of the suture is at the level of the musculotendinous junction and (2) a portion of the suture presents upon the superficial surface of the tendon. It is at this point that the removing wire is fastened.

8. The medial end of the suture is passed through the subcutaneous tissues and brought out through the medial incision. (Fig. 1B, 3.)

9. The proximal tendon fragment is pulled distalward by traction on the wire suture until apposition of the fragments has been obtained. The ends of the suture are then fastened to the screw. (Fig. 1B, 2.)

10. Insertion of the screw is then completed. This carries the medial end of the suture into a subcutaneous position along with the screw head. A small nut is screwed down to the lateral surface of the os calcis and the superfluous portion of the screw removed with a wire cutter.

11. Snug and accurate apposition of the fragment ends is completed by a few mattress sutures of fine silk, (Fig. 1B, 1.)

12. A removing wire is fastened to the horizontal portion of the main suture. This is left about 1 inch in length and a split lead shot clamped to the end. (Fig. 1B, 4.)

The wound is closed in layers over the entire fixation apparatus. Both ends of the bolt and the lead shot on the removing wire occupy a relatively subcutaneous position and remain easily palpable. Removal requires a small incision at each of these three palpable points. Local infiltration with procaine hydrochloride provides adequate anesthesia for this purpose. The terminal ends of the main suture are divided and the bolt mechanism unscrewed and removed through the two distal incisions. The lead shot is then identified by palpation and the remainder of the apparatus withdrawn through the proximal incision by traction on the removing wire

Repair of the Quadriceps Mechanism. An operative technic similar to that described for tendo achillis lesions has been utilized for the repair of various tendon ruptures at the knee. In tears of the quadriceps tendon the traction suture is placed at the musculotendinous junction and anchored to a bolt through the patella,

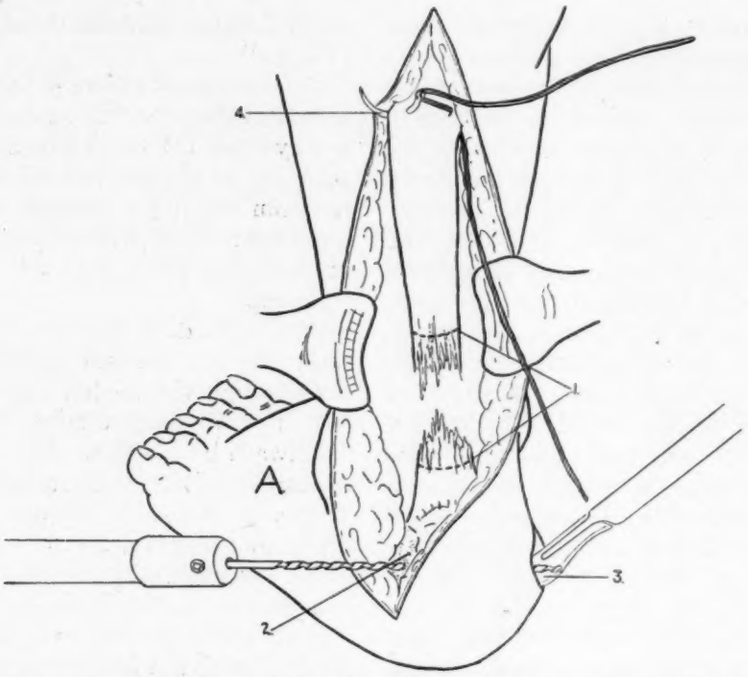

FIG. 1. A, technic for repair of tendo achillis. A, the rupture is exposed and the tendon ends débrided back to healthy tissue (1). A small area on the lateral aspect of the os calcis is exposed and a hole drilled transversely through the bone from lateral to medial (2). A small stab wound is made at the point of emergence of the drill on the medial side of the hole (3). A mattress suture of stainless steel wire is placed through the proximal tendon fragment at the musculotendinous junction (4).

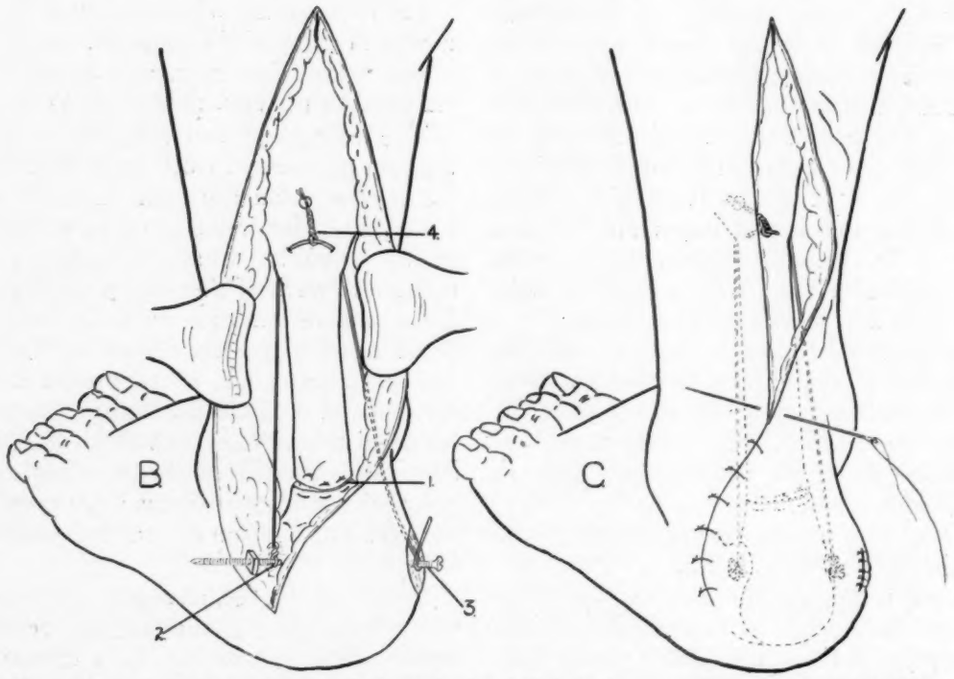

FIG. 1. B, a long screw is passed through the drill hole from medial to lateral (3). The proximal fragment is pulled down into position and the ends of the mattress suture attached to the screw (2). Apposition sutures of fine silk complete the repair (1). A twisted removing wire to which is attached a split lead shot is fastened to the proximal loop of the main suture (4). C, insertion of the screw bolt is completed. A small nut is screwed into the lateral side of the os calcis and the superfluous portion of the screw removed. The wound is then closed over the entire fixation apparatus.

(Fig. 2B.) In patellar tendon tears the suture is placed just proximal to the patella and anchored to a bolt through the tibial tubercle. (Fig. 2A.) A suture placed at the musculotendinous junction and anchored to a bolt through the tibial tubercle has been utilized for temporary protection of the reconstructed quadriceps mechanism during the healing period following removal of the patella.

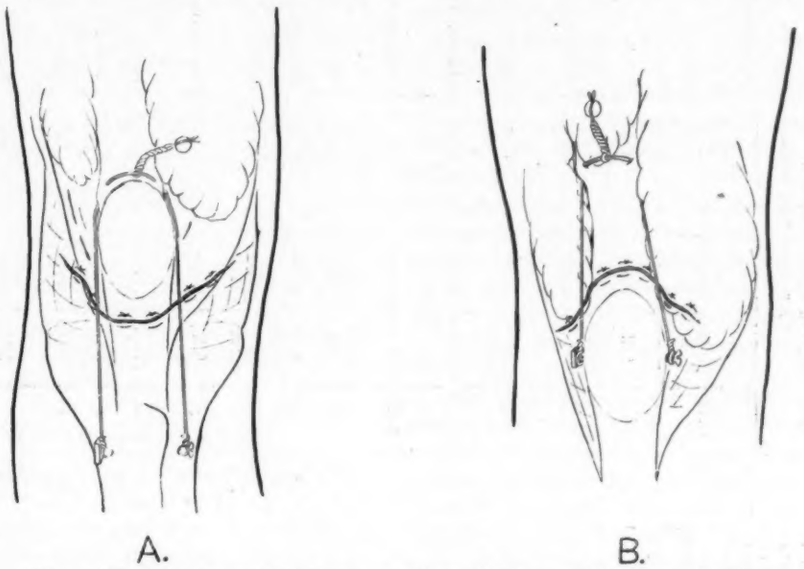

FIG. 2. Technic for repair of ruptures through the quadriceps mechanism. A, repair of rupture distal to patella; B, repair of rupture proximal to the patella.

Postoperative Management. At all operations for repair of the quadriceps mechanism, just prior to skin closure, the knee joint is passively flexed to determine the arc of motion possible before significant tension occurs at the repair site. Usually this is in the neighborhood of 30 degrees from full extension. Postoperatively the extremity is put at complete rest for forty-eight to seventy-two hours and then placed in balanced suspension. All joints except the knee are mobilized fully. The knee is mobilized throughout the arc predetermined at operation. When the operative wound has healed ambulation with weight-bearing is begun with the involved knee protected by an extension splint or brace. The internal fixation apparatus is removed eight weeks following operation. At the same time all external protection is removed and progressive resumption of normal activities encouraged. As a result of early mobilization followed by subsequent continuous active function the penalties of restricting joint motion by the protective splint or brace are minimized and ambulation made safe and possible throughout the period required for tendon healing. The results in four patients treated by removable traction suture appear in the accompanying table. (Table 1.)

Tendo achillis repairs are placed on a postoperative program determined by the individual circumstances of each case. One bilateral lesion required no external support but was prohibited from bearing weight until the fixation was removed. Another patient was not allowed to bear weight until the fixation was removed because of a local infection around the bolt. A third patient was allowed to ambulate with crutches and a raised heel as soon as the operative wound was healed. Two patients were allowed to ambulate in a plaster of paris walking boot following wound healing. Two other patients were made to walk on crutches with the repair protected by a removable plaster splint until the tendon was healed due to poor consistency of the tissues at the repair site. The fixation apparatus is removed from tendo achillis repairs six weeks following operation. The knee joint required immobilization in none of the eight complete ruptures treated by a removable suture. The results appear in the accompanying table.

CONCLUSIONS

The results following surgical repair of major tendon ruptures by direct suture, reinforced or

TABLE I

Case No.	Name	Age	Tendon	Duration	Postoperative Program	Ambulation with Weight-bearing (in Days)	Suture Removed (in Weeks)	Knee or Ankle Range on Removal	Ordinary Full Activities (in Weeks)	Unrestricted Full Activities (in Weeks)	Return to Work (in Weeks)	Follow-up—4 = 100% normal, 3 = 75 to 99% normal					Occupation	Complicating Factors
												Anat.	Range	Sympt.	Econ.	Duration		
1	M. O.	61	Infrapatellar	3 mo.	Knee mobilized then splinted in extension	25	8	50°	4	12	14	4	full	none	4	2½ yr.	Clerk	Incipient paralysis agitans
2	W. A.	46	Infrapatellar	3 da.	Knee mobilized then splinted in extension	15	..	.....	....	..	..	Still under treatment			..	.....	Teacher	
3	M. N.	33	Quadriceps	1 da.	Knee mobilized then splinted in extension	22	8	35°	12	16	12	4	30° short	none	4	1 yr.	Housewife	Compound injury to knee joint
4	S. I.	56	Quadriceps	1 da.	Knee mobilized then splinted in extension	23	10	45°	5	16	18	4	full	none	4	6 mo.	Housewife	Pulmonary infarct, postoperative
5	M. T.	56	Quadriceps	6 mo.	Knee mobilized then splinted in extension	18	..	.....	....	..	..	Still under treatment			..	.....	Housewife	
6	R. H.	26	Patellectomy	1 da.	Never immobilized	32	5	45°	8	10	..	3	full	none	4	1 yr.	None	Psychotic
7	W. R.	42	Tendo achillis	1 da.	Never immobilized	13	6	normal	3½	7	8	3	10° defect	none	4	1 yr.	Probation officer	
8	M. S.	58	Tendo achillis	1 da.	Mobilized then crutches and removable splint	56	6	5° short of normal	6	10	2	3	5° defect	early fatigue	4	6 mo.	M.D.	M.D.
9	I. W.	53	Tendo achillis	5 da.	Mobilized then crutches and removable splint	56	6	?	12	12	3	4	full	none	4	1½ yr.	Executive	Wound infection
10	L. R.	26	Tendo achillis	6 wk.	Mobilized then walking boot	10	6	?	10	14	..	Lost	.....	.....	..	.....	None	
11	H. V.	28	Tendo achillis	9 mo.	Mobilized then walking boot	10	6	normal	6	8	2	4	full	none	4	2 yr.	Athletic coach	
12	E. B.	45	Tendo achillis	2 da.	Mobilized then removable splint	42	6	30°	12	16	2	4	full	none	4	1½ yr.	Executive	
13	A. R.	49	Tendo achillis	2 da.	No external support	56	6	30°	16	24	3	4	full	none	4	2 yr.	Executive	Bilateral lesions
14	A. R.	49	Tendo achillis	2 da.	No external support	56	6	30°	16	24	3	4	full	none	4	2 yr.	Executive	Bilateral lesions

not by fascial or other heavy sutures or free grafts, have been characterized by prolonged disability time due to stiff joints, weak muscles and often an incomplete eventual recovery.

A method of internal fixation for such fractured tendons, utilizing the removable traction suture principle evolved by Bunnell, has been carried out in six lesions of the quadriceps mechanism and eight lesions of the tendo achillis.

The results to date have been characterized by a more complete return to normal in less time than was previously possible.

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DISCUSSION

Sterling Bunnell (San Francisco, Calif.): It is with pleasure that I listened to Dr. McLaughlin's paper developing the use of removable stainless steel wire in the repair of large tendons. This principle in repairing either small or large tendons allows us to avoid using chromic catgut or silk. The knots of the former are a repeated source of trouble. Silk is a foreign body about which a zone of cicatricial tissue undesirable at a tendon juncture always forms.

Stainless steel wire for tendon sutures causes the least tissue reaction to produce adhesions. Tantalum is unfit as it is brittle and rough. After three or four weeks the suture should be withdrawn as by then the tendon has become physiologically united and any suture material is just an irritating foreign body. The suture which gives the least irritative reaction to form adhesions is the suture which is not there.

Tendons pull from one end only, the muscle end, so the suture may be placed in only one of the ends, the two ends lying passively apposed to each other. This suture may even be placed at a distance so no suture material is present at the juncture to interfere with healing or to cause adhesions. The suture is given firm anchorage outside the skin.

I have used this method a great deal in hands and also for large tendons. Certain aspects should be mentioned: One is that when we place a suture in a tendon we must make sure it will withdraw. The hemostat attached to the tendon end is held firmly and the suture and pull-out wire are drawn back and forth until they run freely, just as we test a subcutaneous suture.

A pull-out wire should not have a large loop as tissue may grow through it hindering its withdrawal. To prevent this the loop should be closed but not too tightly as it may break. If the suture does not withdraw, a rubber band applied usually delivers the wire over night; the tissues yield as does a cake of ice when a wire is held taut against it. To prevent tissue from growing in between two strands of the pull-out wire, these are merely twisted a little.

If the patient is allowed to be ambulatory, it is extremely important to immobilize the anchorage of the wire completely. When a wire passing through the skin is fastened to a button or shot it will, because of motion, break unless held firmly by adhesive. As yet I have not encountered infection from the wire, but this is possible in the presence of motion just as is so frequently found about pins placed in bones. Dr. McLaughlin immobilized by using a screw placed in the calcaneus. I have placed a wire around the calcaneus.

The use of withdrawable stainless steel suture has wide application, having been proved successful in closing abdomens, uniting tendons to bones in hands and feet and in joining ligaments in any region. Complications from silk or chromic catgut are avoided and strong union is maintained until physiologic union takes place. Adhesions are reduced to a minimum. In fixing tendons to feet, one can drill right through the bone, pass the wire through the drillhole and fasten it to a button on the sole. This is a quick way of attaching tendons to bones anywhere in the body, drilling through the bone and passing the wire on through the limb to be anchored externally. When a fascial graft is placed, as at the acromioclavicular joint or around a dislocated radial head, the fascia is not strong at first, so a stainless steel wire following the fascia around the bone may be used to hold the joint in place until the fascia is viable and strong. With a local anesthetic, as Dr. McLaughlin stated, the wire can then be removed.

J. Huber Wagner (Pittsburgh, Pa.): Dr. McLaughlin asked me to discuss this paper and I am very glad that Dr. Bunnell was here to open it rather than myself, because I am sure his remarks were more pertinent than mine will be.

Dr. McLaughlin has shown us a very nice adaptation of the principles of the use of stainless steel wire for tendon repair as advocated by Dr. Bunnell. In these particular injuries, in my experience, I have found these so-called spontaneous ruptures to come in the middle or old-age group. In youth and young adults the cases that we see due to steel cuts, both of the quadriceps and the tendo achillis, the repair is easier and healing early; but in the aged and middle-age group, this method permits, as has been shown by Dr. McLaughlin, the use of the part or the muscles within the physiologic limit, so that the atrophy that rapidly takes place in these individuals is not necessarily eliminated but is certainly cut down to a marked degree.

Very often, one sees the after-results in these ruptured tendons that have been repaired by the use of black silk and other material, with suture only at the site of fracture, with prolonged immobilization and then later a deformity and painful tumor at the site of the repair. This latter needs exploration with plastic resection. The tumor is usually of a zanthomatous nature. With removal of the foreign body and tumorous tissue, the function is improved and the pain materially cut down.

In the use of the transfixation pin or bolt, I would suggest rather the use of a properly measured stainless steel screw with enough projection on either side of the patella or the os calcis. This would give enough anchorage for the wire when applied and would then permit easier removal at a later date. I offer this as a suggestion to Dr. McLaughlin.

HARRISON L. MCLAUGHLIN (closing): I would like to re-emphasize the point Dr. Bunnell brought out about twisting the removing wire. We have made this a routine procedure ever since it was found necessary to re-operate on one patient in order to disengage an untwisted removing wire which had become embedded in newly formed tissue. It takes but a few seconds to twist the wire and eliminate such a possibility. A bolt or screw is used as the anchorage point for the traction suture because this form of fixation has been found easiest to remove. If the suture is placed through a drill hole in the bone, most of its tension is exerted at either extremity of the hole. It has been believed that under such circumstances the wire might cut through the bone because of the strength of the opposing muscle forces when dealing with the lesions of the larger tendons.

In the early cases an attempt was made to make the bolt exact in length. However, it was so easy to remove the superfluous portion that it has now become a routine practice to use a longer screw than necessary and cut it down to exact length with a large pair of wire cutters after it is in place.

I expected to be asked whether or not the wire suture has shown any tendency to cut through the tendon proximal to the repair site. It has not done this in any case. This is probably due to the fact that the suture is placed through healthy tendon tissue as far proximal to the rupture as is possible, and to the fact that it is exposed to intermittent rather than constant tension.

INTRAVENOUS PROCAINE IN THE TREATMENT OF TRAUMA*

PRELIMINARY STUDY†

DAVID J. GRAUBARD, M.D. AND HENRY H. RITTER, M.D.
New York, New York

PAIN and post-traumatic edema are perplexing problems for the surgeon. The osteoporosis associated with edema which appears at a later date is more troublesome. During the past year in an attempt to solve these problems we have given 303 intravenous procaine† infusions to 140 patients suffering from trauma. Some of our results seem to indicate that procaine administered intravenously does lessen the edema and pain. For a time we were of the impression that the healing process was accelerated; however, the number of cases is too few to warrant any definite conclusion.

Following trauma the response of the tissues is a defense mechanism. The vasospasm and the exudate which are found at the site of trauma subside in the majority of instances at the conclusion of the healing process. If, however, the vasospasm and the edema persist, an irritative focus is said to exist. In most of our patients we believe that we were able to alter the reflex arc which produces these manifestations so that pain, spasm and edema were reduced. We believe, too, that the healing process was accelerated.

PATHOLOGIC PHYSIOLOGY

It is the consensus of opinion that histamine[2] or a histamine-like substance[3] is liberated at the site of trauma and that a three-fold complex result follows: (1) hyperemia; (2) increased permeability of the vessels and (3) increase of the local lymph and venous circulation.[4] Histamine is said to act as a persistent stimulus to the sensory endings of the terminal axon branchings. The chemical and structural similarity between acetycholine, choline and procaine, which is a local anesthetic, has been shown.[1] Since it is agreed that vasodilatation will relieve the pain syndrome, it must be concluded that histamine is not an effective producer of acetycholine at the terminal junction of the axon branchings because of (1) the failure of hyperalgesia to appear about the site of trauma following local injury while a local anesthetic holds and (2) experimental evidence of vascular contractions prevailing over local vasodilatation due to histamine.[5,6] It should be noted that there is some experimental evidence as to the existence of a spinal outflow of parasympathetic fibers which can produce a cholinergic response by reflex stimulation of a depressor nerve.[7,8]

Whether one calls the reaction a local disorder or reflex[9] the nervous responses are the same. The irritation of the nerves of the skin, muscles and blood vessels produce a vasospasm.[10–12] Vasospasm plays an important rôle in the mechanism of pain.[13,14] This reflex may spread centrally to involve entire limbs.[9,15,16] It has been reported that renal anoxia was found following trauma of an extremity as a result of stimulation of the sympathetic nerves of the extremity rather than the peripheral circulation.[17]

Edema following injury is due to (1) capillary permeability and decompensation and (2) increased collateral circulation. Histamine increases the permeability of capillaries.[18,19] The dysfunction or decompensation is due in part to venous congestion.[20–22] In the pathologic state the capillary membrane may become as permeable to colloids as it formerly was only to ions.[23–26] It is postulated tl at the increased blood flow in the injured extremity results from resistance by edema to the passage of oxygen into the tissues; that the effect of this in addition to (and in spite of) increased blood flow is tissue anoxia.[27] Leriche has demonstrated the extensiveness of the collateral circulation[28] and others have shown the establishment of arteriolar-venular anastomosis.[29,30]

Direct treatment to the affected neuron is

† Procaine used in this study was "Novocain," generously supplied by the Department of Medical Research, Winthrop Chemical Co., N. Y., N. Y.

* From the Traumatic Surgical Service of the Reconstruction Hospital Unit, New York Post-Graduate Medical School and Hospital.

the treatment of choice.[31] Local infiltration of procaine at the site of trauma,[32,33] although satisfactory, presents many disadvantages in that complete anesthesia is not always accomplished; "after pains" are usually present and frequent repetition is required. Knowing that at the site of trauma capillary permeability would allow procaine to enter the tissues it was believed that the vascular approach would produce better and more rapid results.

One is familiar with the boggy, cold and painful ankle following a Pott's fracture, wherein the disability of twelve to fourteen weeks or longer is anticipated, due not so much to the failure of bony union as to soft tissue changes with mild or severe vasospasm and osteoporosis of various degrees.[34] To summarize, we believe a prolonged stimulation of pain impulses reaching the injured, irritable, non-insulated sensory neuron through an antidromic reflex arc may perpetuate itself in a vicious circle of reflexes. The constant circling within the internuncial pool will include the sympathetic motor neuron cells in the lateral horn. Vasospasm at the arteriolar and venular portions of the capillary increases the filtration pressure with the formation of edema and swelling. Anoxia and cyanosis increase capillary permeability and edema. There are three sensory levels: the primary or peripheral, the secondary or spinal and the tertiary or cerebral. Although treatment of the primary neuron is advocated, many have attacked the secondary neuron or sympathetic pathway.[35] Procaine injection administered intravenously blocks the primary neuron at the source of irritation. It has been proven that procaine given intravenously will be concentrated seven to eight times more in traumatized tissue than in normal tissues.[36]

Dosage. The dosage we have employed is the "procaine unit":[1,37] 4 mg. of procaine hydrochloride per kilo body weight dissolved in an isotonic saline solution to make a 0.1 per cent (1:1,000) solution to be administered in a twenty minute period. Using the flowroter,[38] an instrument which measures the number of cc. of solution entering the patient's vein per minute, the administration is simplified and controlled. The error factor by this method is less than ½ of 1 per cent.

CLINICAL DATA

All our cases were treated as outpatients or inpatients. No premedication such as barbiturates was given. No sensitivity to procaine has been found in over 2,000 infusions given for various conditions. In this series of traumas the youngest patient treated was seven years of age and the oldest was seventy-nine.

TABLE 1

Classification	No. of Cases	No. of Infusions
Fractures	55	91
Postreduction arthralgia	8	33
Sprains	14	14
Intervertebral disc	7	14
Myofascitis	18	46
Traumatic arthritis	7	24
Causalgias	30	80
Miscellaneous lacerations	1	1
Total	140	303

Table 1 represents the number of cases treated in this series with the number of injections given in each subdivision. The fractures treated were seen within twenty-four to forty-eight hours after trauma, the variation in time representing the period between the time of trauma and the admission to the hospital.

Fractures. The fifty-five cases represented fractures of various types, excluding compound fractures, and involved most parts of the body. Thirty patients were given procaine infusions prior to reduction with considerable relief of pain but in only two cases was reduction possible under this anesthesia. It should be noted that procaine given intravenously is not satisfactory as an anesthetic. The other twenty-five patients were treated postreduction and all had immediate relief of pain to a greater or lesser degree. The repetition of infusions was necessary because, although the pain which returned was very mild, complete relief was desired. Postreduction sedatives were not necessary.

CASE REPORTS

The following cases are typical in our series:

CASE 1. No. 36259. E. M., a sixty-one year old female, a schoolteacher, fell and injured her left wrist sustaining a Colles' fracture as well as a fracture of the styloid of the ulna with displacement. Reduction was accomplished under general anesthesia and plaster of paris splints were applied.

The first day after the accident the patient complained of throbbing, burning pain in the left

wrist and hand. Examination revealed marked swelling of the fingers and dorsum of the hand and inability to move her fingers. The weight of the patient was 50 Kg. and she was given 200 cc. of 0.1 per cent procaine hydrochloride solution. Immediately following the infusion there was marked lessening of pain and she was able to move her fingers more freely. The patient stated on the third day that she had no pain. The edema had subsided requiring readjustment of splints. Ten days after the accident a radiologic examination revealed early callus formation. Splints were discarded and early motion was encouraged. Fourteen days after admission the patient reported that she was doing housework without pain except when extreme flexion or extension of the wrist was required. A procaine infusion was given and active and passive extension and flexion of the wrist was accomplished without pain. Six weeks after the accident occurred the patient was discharged with no evidence of disability.

Case II. No. 37715. M. F., a forty-three year old female clerk, tripped and fell injuring her left ankle twenty-four hours prior to admission. Examination revealed a markedly swollen and edematous ankle and foot. Radiologic examination revealed a non-displaced transverse fracture through the distal end of the fibula. Her weight was 65 Kg. and 260 mg. of procaine hydrochloride were administered intravenously. There was immediate relief of pain and active motion in the ankle caused no pain. Plaster of paris splints were applied.

Three days later procaine infusion was repeated because of slight pain and a plaster casing was applied. After twelve days the casing was removed and radiologic examination revealed partial obliteration of the fracture line. The patient was able to wear a shoe and able to walk. There was no pain twenty-one days after admission. Only slight dependent edema could be noted. Radiographic examination revealed healing of the fracture. Six weeks after the accident the patient was discharged.

Postreduction Artbralgia. There were six patients with dislocation of the shoulder and two with dislocation of the elbow. They were all reduced under general anesthesia and had severe postreduction pain and limitation of motion. The elbow cases, in addition, had severe swelling due to hemorrhage. Procaine administered intravenously produced immediate relief of pain in all instances. Repetition was deemed necessary in order to diminish muscular spasm.

Case III. No. 36448. R. M., a twenty-five year old male delivery boy, fell injuring his right shoulder. Reduction was accomplished under general anesthesia and the arm was fixed to the chest wall and the forearm suspended.

One day later his weight was determined as 64 Kg. and 256 mg. of procaine were given for the severe shoulder pain. He obtained immediate relief. The next day procaine infusion was given, the bandage removed and active motion started. Slight restriction of motion was noted. Four days after the accident active motion was equal to the opposite extremity except for slight muscular spasm. Procaine infusion was given. The patient returned to work on the seventh day following the accident symptom-free and on the twenty-first day after the injury he was discharged with no evidence of disability.

Case IV. No. 36438. A. K., a thirty-nine year old male accountant, slipped on the ice and sustained posterior dislocation of the left elbow. Reduction was accomplished under general anesthesia. Edema and hemorrhage were so severe that upon flexion of the elbow obliteration of the radial pulse was noted. His weight was 68 Kg. and 272 mg. of procaine were administered. The throbbing pain was relieved and passive flexion could be accomplished without obliteration of the radial artery.

The second week after the injury there was marked reduction in the swelling and edema about the elbow. There was a 10 per cent limitation in flexion and extension. Procaine infusion was given. The patient returned to work three weeks after the accident and extension was restricted 10 degrees; flexion was normal. The patient was discharged symptom-free six weeks after the injury occurred. The total number of infusions was eight.

Sprains. All these cases involved the ankle and radiographically revealed no evidence of fracture. The reduction of pain and the increase in mobility were noted immediately after an infusion of procaine. Repetition was not required and patients were symptom-free during the period of observation.

Intervertebral Disc Rupture. All of the cases in this series were found to have rupture of the intervertebral disc at operation. Procaine administered intravenously does not relieve the pain or spasm in this condition. These cases are typical of the pain syndrome due to direct pressure. It has been reported[1] that this method is being used as a differential diagnostic aid in determining low back pain.

Myofascitis. The low back pain syndrome due to an inflammatory condition responds very satisfactorily following the intravenous administration of procaine. The reduction of pain and the diminution of spasm were noted immediately. The relief of pain is immediate

and usually lasts several days at which time the pain that does return is considerably less. The average patient requires approximately three infusions in a two week period. Observation of these few patients for two months following the beginning of the treatment revealed no recurrences.

Traumatic Arthritis. In a recent report[39,40] we discussed the dramatic relief of pain and increased mobility in traumatic arthritis. The following case is typical in the series:

Case v. No 35058. H. R., a thirty year old single male clerk, sustained a fracture through the left elbow joint two years prior to admission. He suffered a great deal of pain and limitation of motion. His weight was 50 Kg. and he received 200 mg. of procaine. The relief of the pain and spasm was immediate. For the past six months there has been no recurrence of pain or disability in the left elbow joint.

Causalgias. The symptom complex of reflex sympathetic dystrophy has always been a challenge to the surgeon. The effect of procaine administered intravenously in these patients is dramatic The action of procaine given intravenously is at the primary or peripheral neuron.

Case vi. No. 20319. E. F., a thirty-nine year old single female clerk, sustained a sprain-fracture of the cuboid of the right ankle one year prior to admission. She had pain, swelling, hyperhydrosis and marked sensitivity to thermal changes. Examination revealed a mild cyanotic swelling over the dorsum of the foot with marked sensitivity to pressure and examination. Radiographic examination showed osteoporosis of the metatarsal bones. Her weight was 60 Kg. and 240 mg. of procaine were given intravenously. There was immediate relief of pain and tenderness and there was a return to normal of the color of the skin. It is now six months since her first and only infusion and there has been no return of symptoms. Radiographic examination three months ago revealed no evidence of osteoporosis.

Miscellaneous. There was one patient with a laceration of the dorsum of the hand which, in our early investigation, we attempted to repair under intravenous procaine analgesia. The operative repair was performed without difficulty and without pain. This patient is mentioned as a suggestion in the management of severe lacerations in which general anesthesia is contraindicated or regional anesthesia not feasible.

COMMENTS

Most peripheral pain is bound to cause a reflex vasoconstriction in the same and also in other vascular areas. That vasospasm interferes with the normal healing process is well established. In the limited number of our fracture cases in which intravenous procaine was used, the early manifestations of increased mobility, relief of pain, evidence of early callus formation in some instances, as well as the obliteration of fracture lines, prompted us to investigate the healing process of fractures in experimental animals. Our first preliminary study in forty rabbits whose femurs were fractured and the animals sacrificed at stated intervals has revealed no difference in the formation of osteoid tissue, calcification or callus formation. Twenty of these rabbits were treated as controls. Histologically there was no change in the soft structures at the site of trauma. Radiographic comparisons were not conclusive. Despite the discouraging experimental results further investigation along the above mentioned lines is the subject of our present study.

SUMMARY

There is evidence, as a result of our investigations, that interference with the reflex arc established following trauma will hasten the recovery and rehabilitation of the injured individual.

CONCLUSIONS

1. Intravenous procaine is a safe hospital procedure provided the administration is controlled.
2. Relief of pain and spasm has produced beneficial results.
3. The action of intravenously administered procaine in the healing of fractures is the subject of present study.
4. Early rehabilitation is helped by this method.

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KIRSCHNER WIRE TRACTION IN ELBOW AND UPPER ARM INJURIES*

FREDERICK M. SMITH, M.D.
New York, New York

FREQUENTLY certain injuries in the region of the elbow require something more be done than simple closed reduction of the fracture followed by immobilization for a set period of time. Not only is it necessary to alter the usual form of conservative treatment in order to obtain a better reduction and to retain as much function as possible in the joint, but it is imperative that serious complications such as Volkmann's ischemic paralysis, myositis ossificans and permanent nerve injuries be avoided. The routine use of the Jones position of acute flexion of the elbow is not only too frequently used after reduction is obtained, but one might surmise from reading some of the older text books that this position was advocated for the purpose of reducing the fracture. Under no circumstances should acute flexion be used *to reduce* a badly displaced supracondylar fracture of the humerus and even after reduction this position should not be used if it interferes in any way with the radial pulse. If this rule were followed, an ischemic paralysis would very rarely result. Myositis ossificans could largely be avoided if repeated unsuccessful attempts at closed reduction were not carried out and if passive motion, forceful stretching exercises, etc., were not given subsequently in the false belief that they assist in rapid recovery of function. Permanent nerve injuries could likewise be lessened by early reduction which does away with compression of the nerve or by the omission of repeated attempts at reduction which may cause additional trauma during each procedure.

An attempt has been made during the sixteen years between 1930 and 1945 at the Presbyterian Hospital, New York City, to study a particularly useful method of treatment in a large number of cases and the results of this study are highly gratifying from the standpoint of immediate care of the patient and also from the late follow-up results.

The method of Kirschner wire skeletal traction, though not originated at this institution, has been considered by the members of the staff of the Fracture Service to answer many of the difficult problems in the treatment of elbow and upper arm injuries that could not otherwise be readily or safely solved. This method of skeletal traction as applied through the olecranon process of the ulna has been used extensively in two groups of cases. The first group consisted entirely of the more serious type of supracondylar (or transcondylar) fracture of the lower humerus in children. The second group of cases included a rather wide variety of injuries in the lower extremity of the humerus, the humeral shaft and upper extremity of this bone, largely, but not entirely in adults. In the first group of supracondylar fractures in children the method has been most satisfactory and has frequently been the only safe method available. It might be well to explain that much the same form of treatment and possibly equally good end results may be obtained by means of the Dunlap method of skin traction. The reason we have not tried this latter method extensively is because we got started on the Kirschner wire form of traction several years prior to the use of Dunlap traction and found it so satisfactory and in some ways preferable to the other method that we have continued its use.

The second main group of cases treated with Kirschner wire traction has been very satisfactory in particular types of injuries, but much less so in others. An analysis of the cases has convinced us that the method, even if not completely satisfactory as a means of maintenance of reduction, may have considerable advantage as an ante-operative or postoperative adjunct to surgery. These cases will be discussed further on in this paper.

THE USE OF KIRSCHNER TRACTION IN SUPRACONDYLAR FRACTURES OF THE HUMERUS IN CHILDREN

Approximately 60 per cent of all children's supracondylar fractures are of a mild variety with little or no displacement of the distal

* From the Fracture Service of the Presbyterian Hospital and the Department of Orthopedic Surgery, College of Physicians and Surgeons, Columbia University, New York, N. Y.

fragment. These require either no reduction or merely flexion and splinting in this position. In these the loss of position of the distal fragment is mainly angulation rather then actual shift of the fragment. The remaining 40 per cent of supracondylar fractures in children are serious from the standpoint of displacement and soft tissue swelling. The surrounding soft part damage is directly proportional to the type and amount of displacement of the fragments. All of these require reduction and the sooner that this is accomplished and the more completely it is accomplished, the better are the chances for overcoming any circulatory embarrassment. Of these supracondylar fractures requiring reduction about 75 per cent can be reduced adequately by traction and manipulation under general anesthesia, and the reduction can be maintained by immobilization of the elbow in a posterior molded splint in flexion to a degree which will not compromise the radial pulse. However, about one-fourth of these serious supracondylar fractures (comprising approximately 10 per cent of all supracondylar fractures) are extremely serious cases even when treated by skilled surgeons and in well equipped hospitals or clinics. The reasons for this are: (1) Immediate circulatory damage and the possible threat of Volkmann's ischemia; (2) difficulty in reducing and maintaining reduction of the fracture; (3) frequency of other associated lesions to bone or the surrounding soft parts; (4) late deformity with reversed carrying angle at the elbow and (5) myositis ossificans.

How many times has one met with such difficulties? The answer is "all too frequent" if one has treated more than a few dozen such fractures in children. It is very disconcerting to find difficulty or inability to reduce such a fracture adequately or to be able to reduce it, and to discover that an attempt at flexion results in diminution or obliteration of the radial pulse. Even if reduction and flexion for maintaining the reduction be accomplished, it not infrequently follows that some hours later the pulse becomes feeble or absent owing to delayed swelling around the elbow or to constrictive bandages holding the splint in place. Such a condition, if allowed to persist, will almost certainly lead to Volkmann's ischemia—a major catastrophe. To remove the bandages and splint and to decrease the amount of flexion in order to bring back the pulse will almost certainly allow re-displacement of the fracture fragments. It should be emphasized that Volkmann's ischemia is not always the result of flexion, splinting or tight bandaging. It may occur without any treatment having been instituted. There are also times when the surgeon is "up against it," because there are other fractures in the same extremity; or because the supracondylar fracture was originally compounded (contaminated) and acute flexion of the elbow makes it difficult or impossible to inspect or dress the wound without fear of losing the reduction.

In the more serious cases we have resorted to the use of Kirschner wire traction and overhead suspension and have formulated four criteria necessitating the use of this method. These are: (1) Where it is impossible to reduce the fracture by any other closed form of manipulation; (2) where it is possible to reduce the fracture, but impossible to maintain the reduction by plaster splint or other means; (3) where there is circulatory impairment either before or after reduction (excessive swelling, weak or absent pulse and a question of impending Volkmann's ischemia); (4) where there are other associated lesions in the same extremity, such as additional fractures, nerve injuries or where the original supracondylar fracture is compounded.

METHOD OF INSERTION OF KIRSCHNER WIRE

The insertion of the Kirschner wire should be carried out under strict aseptic technic. In children it is best to do this under general anesthesia, because of pain in handling the arm during the insertion and the setting up of the traction and suspension apparatus. The entire elbow region should be shaved, cleaned with soap and water and painted with iodine and alcohol. An assistant maintains gentle traction on the forearm, and sterile towels are draped over his hands. A small incision is then made approximately 1 inch or slightly more below the tip of the olecranon process of the bone on the ulnar side to avoid damaging the epiphyseal plate. A large bore, No. 15 gauge needle is then inserted in this incision until its point reaches the posterior crest of the ulna; while holding the point of the needle on the bone the operator then moves the entire needle volarly in order to displace the muscles and the ulnar nerve away from the point of the insertion of the Kirschner wire into the ulna. A sterile assistant must then hold this needle point against the

bone and keep the needle in a plane parallel to the posterior aspect of the forearm. The operator uses the needle as a cannula, inserting the Kirschner wire through it, and then drills the latter through the bone. When the point of the needle bulges beneath the skin on the lateral side, a small nick is made over this and the wire brought out on this side. The needle is then removed, the skin wounds are covered with small sterile dressings and a yoke and tightener are then applied to the Kirschner wire. The yoke is then rigged up for traction and suspension as shown in Figure 1.

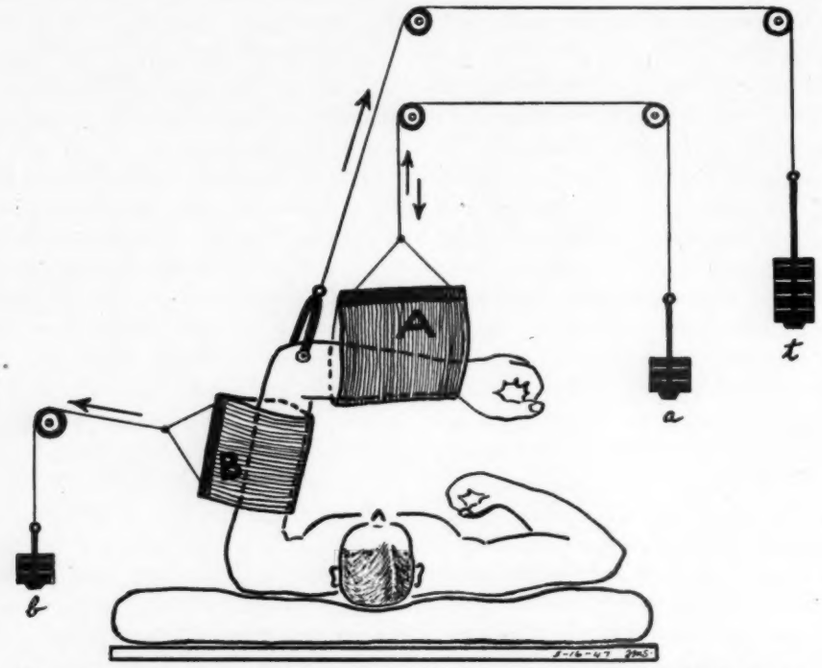


FIG. 1. Sketch demonstrating use of overhead traction and suspension by means of a Kirschner wire inserted through the olecranon. Weight (*t*) provides traction upon the lower humeral fragment via olecranon in a distal and forward direction. The amount of weight necessary is usually between 4 to 6 pounds, depending upon the size of the child. Body weight acts as countertraction. Swathe (A) supports the forearm. Weight (*a*) counterbalances the forearm and assists in exercising the elbow joint while still in traction. This weight usually amounts to 2 to 3 pounds. Swathe (B) is not always necessary but may be applied if additional pull on the proximal humeral shaft is desired in a posterior direction. Weight (*b*) should be 2 to 3 pounds. If rotation of the fragments needs correction, this may be accomplished by changing the horizontal axis of the forearm by shifting the pulley about Swathe (A) toward the head or foot of the bed.

It is sometimes advisable after twenty-four or forty-eight hours of this traction, if the reduction is not completely satisfactory and there remains either some posterior displacement of the lower humeral fragment or rotary deformity, to give the patient a general anesthetic and again manipulate the fracture while it is still in traction, following which the improved position can be maintained by the traction. As swelling and induration rapidly subside it is frequently possible to have the patient begin mild active exercises for the elbow while still in traction and with complete safety. As soon as x-ray films show good evidence of callus formation along the posterior aspect of the humerus, the distal fragment will no longer slip out of position and the Kirschner wire may be removed. The elbow should then be immobilized in a posterior molded splint in moderate flexion as though it were any other fracture reduced and thus splinted. The swelling will have diminished to such an extent by this time that one no longer need worry about development of Volkmann's ischemia from mild flexion. The average duration of time that these patients have been kept in Kirschner wire traction has been approximately thirteen days.

ADVANTAGES OF KIRSCHNER WIRE OVERHEAD TRACTION AND THE REASONS FOR ITS SUCCESS

1. The patient is hospitalized and under constant observation.

2. He is in bed and is unable to fall and reinjure himself.

3. Skeletal traction is employed which is much more efficient than skin traction in obtaining as well as maintaining reduction of the fracture.

4. The injured part is held in high elevation which permits venous and lymphatic drainage to be assisted by gravity, thus permitting rapid decrease in swelling.

5. The Jones position of acute flexion is unnecessary to maintain reduction and thereby circulatory impairment is lessened.

6. There is no necessity for any constricting dressings to maintain position of a splint.

7. The method is painless and thus of extreme importance in children.

8. It allows early active elbow motion without the danger of complete loss of position of the fragments.

9. The anterior aspect of the elbow region is accessible at all times for dressings of a compound wound.

10. The method does not interfere with reduction or immobilization of associated wrist or forearm fractures.

11. It also permits the use of a cock-up splint for the wrist and hand in the event of an associated radial nerve injury.

ANALYSIS OF CLINICAL CASES TREATED BY KIRSCHNER WIRE TRACTION

Group A. Supracondylar Fractures of the Humerus in Children. From 1930 to 1945 inclusive there have been 402 fresh cases of supracondylar fracture of the humerus in children treated on the Fracture Service of the Presbyterian Hospital, New York City. Old cases with complications or malunions have not been included in this number. Of the 402 fresh injuries of this type thirty-nine cases (or 9.7 per cent) have been considered serious enough to warrant treatment by over-head skeletal traction. It has not been our practice to operate upon supracondylar fractures for the purpose of obtaining open reduction of the fragments or for the relief of impaired circulation except in extremely rare instances. The results of this study clearly demonstrate that open operation is unjustified in this type of fracture in general. With the exception of six cases of compound fracture in which operative débridement was a necessity, only three patients (0.75 per cent) of the entire 402 cases had open operation performed upon them.

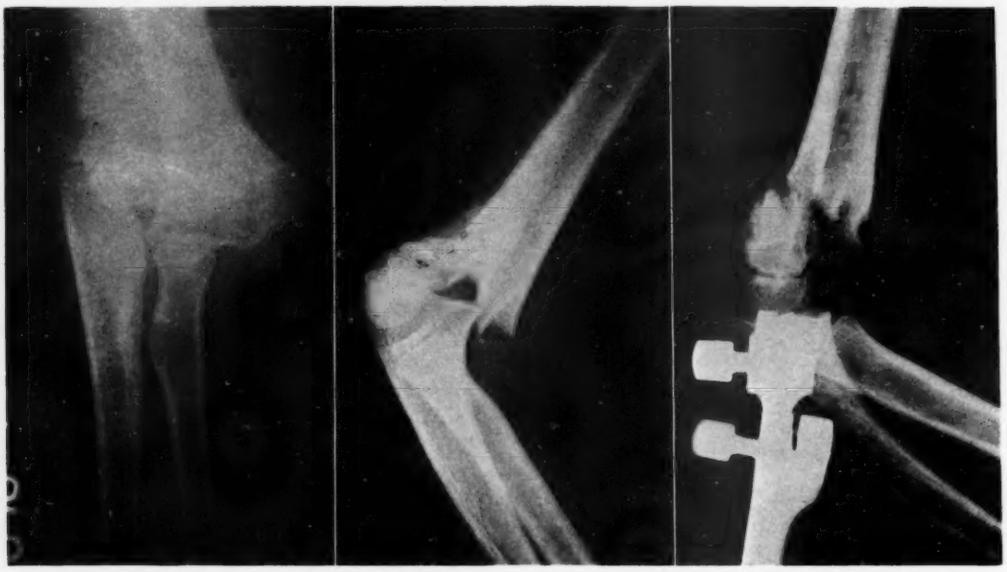
One frequently hears discussed the necessity for open reduction where wide displacement of the fracture fragments is seen on x-ray films, where swelling is excessive and the pulse feeble or absent and where associated nerve lesions are present. In the first place operation carries some risk of infection, does not guarantee maintenance of accurate reduction of the fragments,

TABLE 1

SUPRACONDYLAR FRACTURE IN CHILDREN

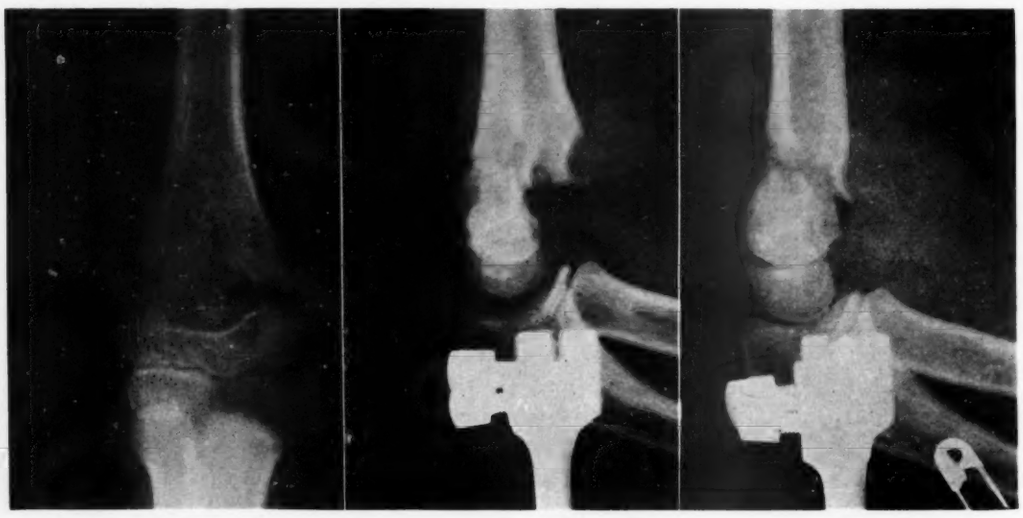
A. Inability to reduce fracture by other closed methods.	2, 3, 4, 10, 14, 18, 26, 32, 36, 38, 39
B. Inability to maintain reduction by flexion and plaster fixation.	1, 9, 11, 13, 16, 19, 21, 22, 25, 29, 30, 34, 35
C. Severe circulatory impairment prior to or after closed reduction.	6, 7, 8, (9), 15, (19), 20, (22), (24), (25), (26), 28, (30), 37
D. Associated lesions (compounding of fracture, other fractures, or nerve lesions).	5 (compound) (10) (fracture shaft of radius and ulna) 12 (compound fracture of wrist) 17 (compound; post. interosseus nerve palsy) 23 (compound) 24 (fracture at wrist; post. interosseus nerve palsy) 27 (compound) 31 (compound; radial and ulnar nerve palsies) 33 (compound) (37) (median nerve palsy)

The case numbers are grouped according to the principal reason why Kirschner wire traction was used in each. Numbers in parentheses are grouped according to additional reasons for use of the treatment.



A B C

FIG. 2. J. G., female, age seven and one-half years, supracondylar fracture of humerus treated by Kirschner wire traction and suspension. A and B, anteroposterior and lateral films showing original displacement. C, lateral view after two days in overhead traction showing some residual posterior displacement.



D E F

FIG. 2. D, anteroposterior view and E, lateral view after four days in traction. The posterior displacement of distal fragment has been largely overcome but some rotation persists. F, lateral view on sixth day of traction and two days following manual correction of rotation deformity under anesthesia.

and, if performed at a period of one to two weeks after injury, it may lead to extensive formation of myositis ossificans. In the second place it is rarely ever necessary to split or decompress the deep fascia overlying the anterior elbow region to overcome circulatory embarrassment if over-head traction is carried out as described. And third, original nerve injuries are usually the result of contusion or pressure from a bone fragment or the result of overstretching. There is little fear of actual severence of one of the nerves in this region except by gunshot or a sharp cutting object. Operation in the presence of severe hemorrhage, muscular damage, etc., may likewise be extremely risky because of distortion of the anatomy and masking of important nerve trunks. It is our belief that Kirschner wire over-head traction is not only safer by virtue of being more conservative but performs all that open operation can do and just as well.

G H

FIG. 2. G, lateral view on sixteenth day after injury, following removal of Kirschner wire and application of posterior molded splint. (Note good position and abundant early callus.) H, lateral view at seven weeks.

I J

FIG. 2. I, anteroposterior and J, lateral views four years four months after original injury. (Result: full function, use and no deformity.)

A B C

FIG. 3. M. McM., female, age nine years; supracondylar fracture of humerus with associated partial paralysis of median nerve treated by Kirschner wire traction and suspension. A and B, anteroposterior and lateral films showing original marked displacement. C, anteroposterior view after one day of traction.

D E

FIG. 3. D, lateral view after three days in traction. E, lateral view after seven days in traction and two days following manual correction of posterior displacement under anesthesia.

F G

Fig. 3. F, and G, anteroposterior and lateral views three and one-half months after original injury. (The wire traction in this case was removed on the eighth day after injury and the elbow was immobilized further in a posterior molded splint until the twenty-fifth day after injury and then in a sling only for two weeks.)

H I

Fig. 3. H and I, anteroposterior and lateral views one year nine months after original injury. (Result: full function, use and no deformity; complete recovery of motor and sensory functions of median nerve.)

There were thirty-nine patients treated by this method. The average age of these children was 7.7 years. Thirty-five of the patients appeared for treatment within twenty-four hours or less after injury; twenty-nine appeared within three hours. In four cases the duration was four, five and seven days, respectively. All but one of these four patients had one or more reductions attempted at other hospitals before coming to us. The majority of injuries were sustained in falls from a bicycle, trees, in the gymnasium or playground, etc. All of the cases showed marked displacement of the lower humeral fragment. In two cases the displacement was in an anterior direction, but in the remaining thirty-seven it was in the usual posterior direction with or without some lateral or medial shift. Six of the cases were compound supracondylar fractures.

Table 1 lists the cases under the reasons why Kirschner wire traction was resorted to and also lists the associated lesions where present. The case numbers in parentheses are additional listings where secondary causes were found for resorting to this method of treatment.

Reduction had been attempted in five patients before admission to this hospital. It was attempted in twenty-four cases by us prior to resorting to Kirschner wire traction and was considered unsuccessful or the reduction could not be maintained satisfactorily without compromising the circulation. In nine cases immediate insertion of the Kirschner wire was performed and subsequently followed by manipulative reduction and then by traction and suspension. Four of these were immediately put up in traction following operative débridement of their compound fractures. It has been stated elsewhere that if Kirschner wire traction and suspension alone does not give complete reduction in forty-eight to seventy-two hours, it may be advisable to give the patient a general anesthetic and manipulate the fragments again while still in traction. The traction should then be continued to maintain the reduction. This had to be done in twenty of the thirty-nine patients treated by this form of traction and resulted in marked improvement in position of the fragments, due partly to muscular relaxation and partly to diminished soft part swelling. (Figs. 2 and 3.) Operation was performed in only two uncontaminated cases of the entire thirty-nine. One was in a four-day old case with extreme swelling and bony displacement and with a feeble pulse; the other was in a fresh case of five hours' duration with no palpable pulse. This latter patient when explored showed extreme spasm of the brachial artery where it was stretched over the sharp, projecting lower end of the humeral shaft fragment. This spasm persisted for at least one-half hour (under direct observation) after the fracture fragments were reduced and the offending disorder corrected.

In general the wire traction has been continued for an average of 13.1 days. The shortest duration of wire traction was for three days which was in the four-day old case which came to operation and was then discontinued. The longest duration for which it was used was twenty-eight days in one case with a separately displaced loose fragment. In the beginning the tendency was to use traction for a shorter period of time, but in the past eight to ten years it has been thought wiser to continue it for a longer period and therefore most of the more recent cases have remained in traction for two to two and one-half weeks. The best criterion for maintaining traction seems to be the presence of good callus formation as seen on lateral x-ray films. In three cases the Kirschner wire has pulled out from the bone due to imperfect original placement of the wire which engaged only the periosteum or a very superficial portion of the bone. It is important to have the wire at least ⅛ of an inch deep to the posterior cortex to prevent such a complication. If the wire should pull out and further traction is necessary, a new one may be reinserted under aseptic precautions. No serious complications have arisen from the wire traction, but there have been a moderate number of minor complications all of which have cleared up. Three patients developed wrist drop, but it was not definitely known whether these complications preceded the insertion of the wire or if they were the result of insertion of it. Posterior interosseus nerve weakness developed in one case. Partial anesthesia of the ulnar nerve developed in one case. All of these nerve complications cleared up completely over a period of several months. Three pressure sores with mild surrounding skin infections resulted from slipping of the wire laterally in the bone, allowing the traction yoke to come in contact with the skin; these cleared up with conservative treatment and none resulted in osteomyelitis or sinus tract infection.

After the Kirschner wire has been removed, we usually immobilize the elbow in mild flexion of 70 to 80 degrees in a posterior molded splint extending from the axilla to the metacarpophalangeal joints; a sling is also applied. The average duration of splinting following removal of the wire has been 14.6 days. Following removal of the splint the arm is supported in a sling only for another ten days to two weeks. Active elbow exercises are frequently begun while the patient is still in traction and suspension and during the last week of wearing the splint. The splint is removed temporarily by the examining surgeon and the patient encouraged to exercise the elbow himself. No passive motion, weight carrying or forceful stretching exercises or heavy massage are permitted in any of these cases and none of them have developed myositis ossificans. We believe this is adequate proof that this form of active exercise (always within pain limits) can do no harm. These patients remained in the hospital on an average of 18.6 days and were carried on active treatment in the out-patient clinic or in the private offices for an average of 10.5 weeks. Maximum function was regained in the elbow joint in an average of 9.2 weeks. Even though some of these patients were slow to recover function, it was believed best not to try to hurry them. In a few cases it was necessary to tie up the patient's uninjured arm inside his shirt so that he would have to use the injured arm. Occasionally, the patient seemed to be impressed with the idea that visits to the clinic indicated that his condition was still serious and that he must do little or nothing to exercise or use the arm at home for fear of harming it. When such a stage was reached (somewhere around two or three months) and progress seemed to be stationary, these patients were discharged from active treatment and given a follow-up date for three months hence. The parents were instructed to allow the child to use the arm at will and not to keep nagging him about using it. On return to this follow-up appointment most of these patients showed very marked improvement in function. Physiotherapy in the form of diathermy treatments given two or three times a week we believe to be definitely detrimental to functional recovery. It is all too frequent that the child relies upon such treatment to get him well and restore his elbow function while the remainder of the time he does nothing about it himself.

The results in this series of thirty-nine patients treated with over-head Kirschner wire traction have in general been excellent. The only residual deformity noted clinically has been a slight loss of the carrying angle at the elbow, or in some, a reversal of the carrying angle giving a mild to moderate "gun-stock" deformity, none of which has required operative correction. The average duration of follow-up for these thirty-nine cases has been five years and three months. Only two patients in the whole group have been followed for less than one year and each of these when last examined showed slight loss of elbow flexion, but no other impairment or deformity. At least five cases have been followed for ten years or longer. Of the thirty-nine cases thus followed fourteen were completely perfect from every standpoint (anatomic, functional and economic). Four more were completely perfect except for 5 to 15

TABLE II

MISCELLANEOUS GROUP OF FIFTY-FOUR CASES IN WHICH KIRSCHNER WIRE TRACTION WAS USED

A. Dicondylar fracture of humerus.	2c, 3, 7, 9, 11, 14, 15, 17, 22, 23, 25, 27, 30, 32, 34, 35, 38, 39c, 40c, 41c, 42c, 46c, 49, 51, 52, 54
B. Fracture of surgical or anatomical neck of humerus.	1, 4c, 8, 10, 13, 19, 26, 28, 36, 37, 50, 52, 53
C. Separation of upper humeral epiphysis.	5, 12, 18, 47
D. Fracture of shaft of humerus.	6, 20,* 21, 24c, 43c, 44, 45c
E. Multiple fractures.	4, 10, 14, 19, 25, 28, 34, 35, (39), (40), 44, 52, 54
F. Miscellaneous.	16 —"Truck-swipe" fracture
	(25)—Fractured ribs, ruptured spleen, cerebral concussion
	29 —Four-year old elbow dislocation (Post-op. traction only)
	31 —Fracture of capitellum, trochlea, radial head and coronoid
	33 —Twenty-four-day old subcoracoid dislocation of shoulder
	48 —Thirteen-day old elbow dislocation unreduced
	(54)—Fracture pelvis and ankle; rupture of urethra

Case numbers are grouped under principal diagnosis; "c" following a number indicates that fracture was compound. Parentheses indicate additional lesions.

* (Paget's disease of humerus)

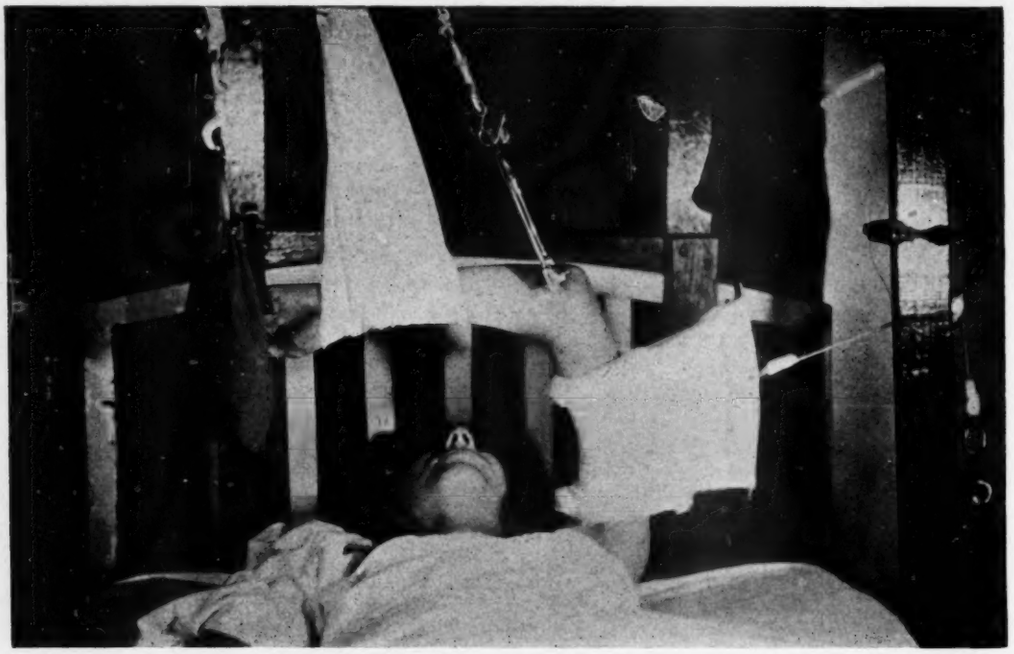


FIG. 4. Female, age twenty-six years, with severely comminuted and badly displaced dicondylar fracture of humerus associated with complete radial nerve paralysis and partial ulnar nerve paralysis. Patient was admitted two days after injury (having received temporary treatment elsewhere) and Kirschner wire skelatal traction was applied immediately as shown in photograph above. Manipulation to overcome tendency of persistent posterior displacement of lower fragments was done on the fifth day. Traction was continued for six weeks following which patient was allowed home with arm in a protective splint and sling. The splint was removed daily for whirlpool baths and active exercises. A cock-up splint was worn on the wrist and electrical (galvanic) stimulation was given daily to the extensor muscles of the wrist and fingers. At the end of four months patient had recovery of active wrist extension but still lacked extension of the fingers at the metacarpophalangeal joints. Neurolysis was then performed on the radial nerve whose motor branch was found densely adherent to the bone at the healed fracture site; three months later the patient had recovered full motor power of this nerve. The ulnar nerve showed complete recovery within six weeks after the original injury; one year one month after injury patient had a range of motion in her elbow of 75 to 155 degrees and pronation and supination were complete. She returned to work as a registered nurse ten weeks after the original injury and has continued to work without handicap except for two weeks following the neurolysis operation.

degree loss of elbow flexion; eleven showed complete function and use, but some loss in the carrying angle only. The remaining ten cases showed some mild loss in function as well as some loss in the carrying angle.

In this particular type of supracondylar fracture in children it is the opinion of the author that no time must be lost in affecting reduction of the fracture and at the same time employing such treatment as will allow maintenance of the reduction without further impairment of the already embarrassed circulation. The method of Kirschner wire traction as described has accomplished this in thirty-nine cases of severe displacement *without a single case of Volkmann's ischemic paralysis having occurred.* Three of the patients thus treated had a threatening Volkmann's ischemia on admission, but this threat disappeared shortly after over-head traction was instituted in each case.

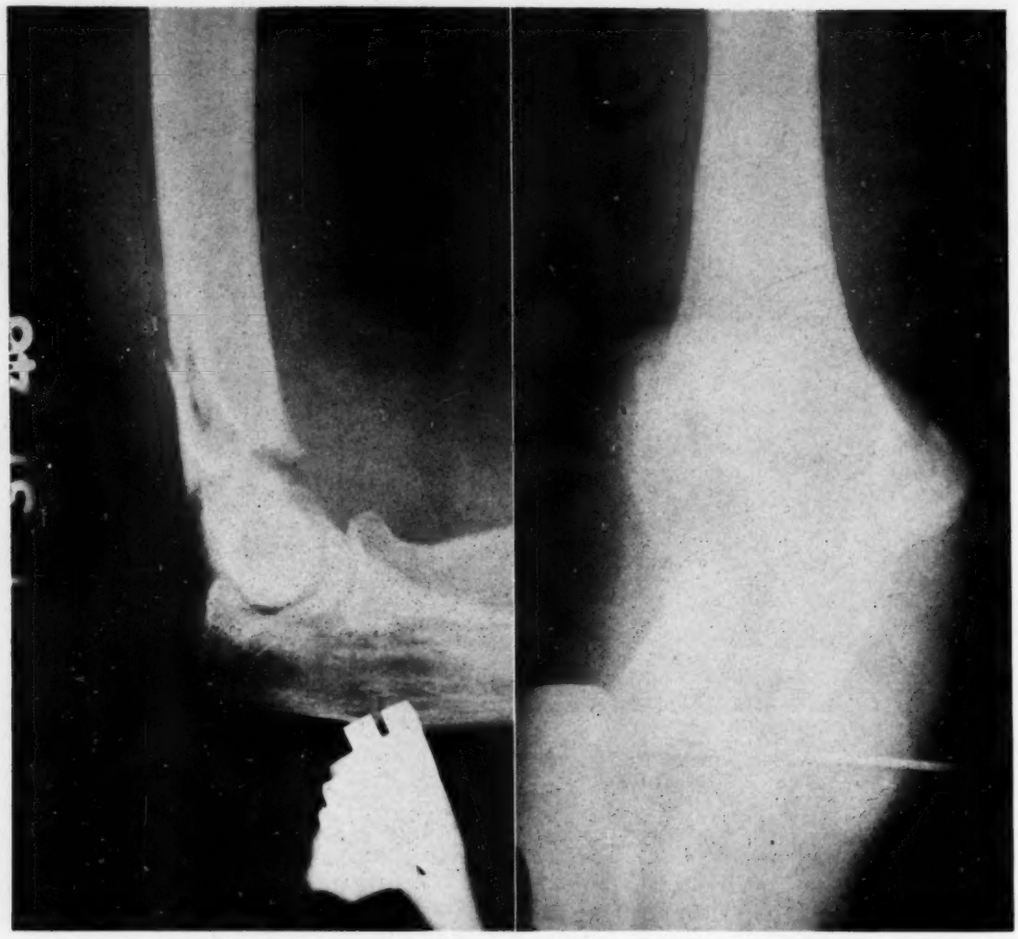
Group B. Miscellaneous Injuries. In addition to the single group of children's supracondylar fractures cited above there has been a somewhat larger group of miscellaneous cases, fifty-four in number, likewise treated by Kirschner wire over-head traction at the Presbyterian Hospital from 1931 to 1945 inclusive. The wire traction has been the main form of treatment in twenty-six of these, but has also been used as a trial prior to operation in five others. In still another group of nineteen cases it has been used as a postoperative method of fixation which not only gave protection, but allowed at the same time active elbow exercise and hastened the disappearance of excessive edema and induration.

A B

Fig. 5. L. H., female, age thirty-nine years; dicondylar fracture of humerus with comminution. This patient had been treated for five days in a "hanging cast" by another physician who referred her here with a note saying, "The hanging cast had not reduced the fracture and she was being referred for operation." It was decided in view of the extensive comminution that reduction could not possibly be accomplished and adequate internal fixation obtained by open operation without resorting to prolonged external splinting which would defeat the purpose of operation and lead to additional trauma and a good chance of a stiff elbow. Consequently, Kirschner wire skelatal traction was used and active exercises in traction were begun on the tenth day. Traction and suspension were maintained for six weeks. A and B, original lateral and anteroposterior x-ray views.

In this whole group there were twenty-six cases of dicondylar fracture of the humerus, seven of which were compound fractures; thirteen cases of fracture through the anatomic or surgical neck of the humerus; four cases of separation of the upper humeral epiphysis; seven cases of fracture of the shaft of the humerus, three of which were compound; thirteen cases of multiple fractures, and a miscellaneous group of seven cases with complicated or multiple injuries. (Table II.)

In order to break this series down still further it has been divided into sub-groups according to the use of the wire traction. The first group in which it was used as the only method of reduction and immobilization consisted of twenty-six cases which come under the following diagnoses: dicondylar fracture of humerus (fourteen cases), fracture of shaft of humerus (one case), fracture of upper extremity of humerus, anatomic or surgical neck with or without tuberosity fracture (nine cases), separation of upper epiphysis of humerus (two cases), and one twenty-four day old subcoracoid dislocation of the humerus. In all but two of these patients Kirschner wire traction was instituted upon the day of admission to the hospital either as a primary procedure or following an unsuccessful attempt to reduce the fracture manually under general anesthesia. The dicondylar fractures with marked comminution and displacement were put up in skeletal traction and only a few of these received subsequent manipulations in an attempt to improve the position of the fragments. Since all were adults they were kept in traction for an average of twenty-two days. Active motion was begun in traction at about one week and continued thereafter. (Figs. 4 and 5.) In others, where it was not begun until after the fourth week, the end results in respect to function in the elbow joint suffered as compared to those in which it was started earlier. It is believed that early active motion in traction helps to mold the comminuted fragments



C D

FIG. 5. C, lateral view after five days in traction; D, anteroposterior view after two days in traction.

into a more favorable position to allow a greater range of motion, but this cannot be expected if the motion is not begun early and is postponed until four or five weeks after injury when new bony callus has "fixed" the fragments. None of these dicondylar fractures thus treated has resulted in bony or fibrous ankylosis. The poorest result had a range of motion of 40 degrees through an arc of 70 to 110 degrees, but she was able to use it in all her housework at the age of sixty-nine years when last seen three and one-half years after her injury. All but one of these cases has been followed from one to eight years and have in general at least 80 to 100 degrees of motion in their elbow joints in a useful range. One patient recovered full range of motion. The cases of anatomic or surgical neck fractures of the humerus were complicated by extreme displacement or with associated tuberosity fractures. These did not show remarkably good results, but perhaps better than could be expected had they been treated as milder cases are with sling and swathe and early pendulum exercises, and certainly better than if they had been treated by means of abduction splints or plaster spicas. The two cases of separation of the upper humeral epiphysis did very well. One was followed for one and one-half years and had a perfect result at that time. The other moved to another state after four weeks, but was well on the way to a good result when last seen, and it is realized that this is not a late follow-up result. The over-head traction followed by manipulation maintained excellent reduction in both cases. The fracture of the shaft of the humerus obtained solid bony union, but we have no follow-up record on him later than thirteen weeks after his injury. The twenty-four-day old subcoracoid dislocation of the humerus was reduced manually after twenty hours of skeletal traction. No late follow-up is available, however.

E F

FIG. 5. E and F, lateral and anteroposterior views two and one-half months after original injury. Result: (one year seven months after injury) active elbow range 45 to 135 degrees; pronation and supination complete; no deformity, full use; strength excellent.

The second group in which Kirschner wire traction was used was in five cases as an anteoperative measure. Two of these were for dicondylar fractures with little comminution. The traction alone failed to give satisfactory reduction, so open reduction was resorted to after five and seven days, respectively. Good position was obtained and held by internal fixation with plate and screws and the late results were excellent. The remaining three cases (one surgical neck fracture, one separation of the upper epiphysis of the humerus, and one fracture of the shaft of the humerus) did not obtain satisfactory position from Kirschner wire traction, so consequently open reduction had to be performed.

The third group in which skeletal traction was employed mainly as a postoperative measure consisted of nineteen cases, twelve of which were complicated by compound wounds. Eight were dicondylar fractures, all but one being compound. Débridement of the wound was performed in all cases and internal fixation was employed in two cases, but was later deemed an error owing to inability to fasten the fragments securely owing to extensive comminution. None of the cases resulted in infection of the compound wound or of the bone. The traction as used following operation was valuable in that it maintained satisfactory position of the fragments and allowed easy access to the wounds for dressing. (Fig. 6.) No other form of immobilization could have been so efficient in this respect. The late follow-up results in six of these cases were good to excellent. This is especially gratifying since four of these patients were over sixty years of age. Of three cases involving the upper extremity of the humerus, one anatomic neck fracture was operated upon and then placed in skeletal traction and obtained an excellent result; one compound surgical neck fracture became infected and obtained a poor

A B

FIG. 6. N. B., female, age twenty-seven years; compound fracture of radial head and dicondylar fracture of humerus from pistol wound. The wound was immediately débrided, the bullet was not removed, the radial head was excised and the arm was put up in Kirschner wire traction. The compound wound healed per primum. Mild active elbow exercises in traction were begun on the ninth postoperative day. Traction was removed on the thirtieth day postoperatively and the patient left the hospital four days later. At the end of five and one-half weeks after original injury the elbow range was 90 to 135 degrees; pronation was 50 per cent normal; supination was nil. The patient moved South immediately after this and did not return again until four years one month after her injury. Elbow range at this follow-up visit was 55 to 175 degrees; pronation was 90 per cent complete; supination was 40 per cent complete. (The limitation of supination was due to an old malunited Colles fracture and not to her elbow according to the patient.) She was able to carry on her full work as a housewife with difficulty. A and B, anteroposterior and lateral x-ray views of original fracture.

result, but this was not the result of the traction; one fracture-dislocation of the head of the humerus with associated brachial plexus injury (following an attempt at reduction by means of placing the heel in the axilla for countertraction at another hospital) subsequently came to operative removal of the dislocated humeral head, but obtained only a poor to fair result—certainly not attributable to skeletal traction.

Four fractures of the shaft of the humerus, three of which were compound, were treated after operation by wire traction. One of these was a gunshot injury with radial nerve paralysis and with marked comminution of the midshaft. It was impossible to use internal fixation or any other form of traction. Union was slow but complete and with minimal deformity. Range of elbow motion seven and one-half years later was complete except for less than 10 degrees loss of full extension. Recovery of radial nerve function was complete by ten months after the original injury. A second patient obtained a good result by the end of six months, but died three months later of a cardiac condition, consequently there is no late follow-up record. In the third case of shaft fracture the humerus was plated and wire traction was used because of an associated fracture of the medial condyle of the humerus and obtained an excellent result except for 20 degrees

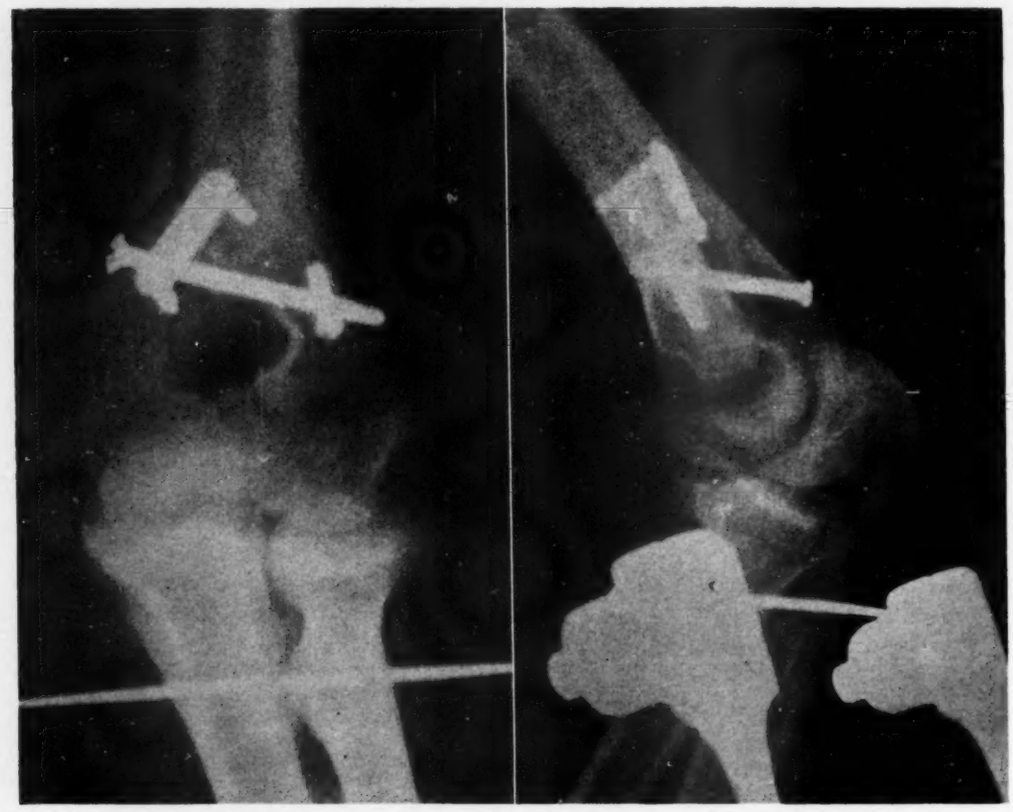
C D

FIG. 6. C and D, same views in Kirschner wire traction.

E F

FIG. 6. E and F, same views after four years one month.

limitation of full elbow extension. The fourth case was in a child in which débridement and closed reduction was done for compound fracture and skeletal traction employed to maintain reduction. A perfect result was obtained. Both of these last two cases have been followed for longer than two and one-half years. A separation of the upper epiphysis of the humerus was operated upon in a seven-year old girl and followed by wire traction because she kept pulling off the skin traction employed immediately after operation. The wire traction was comfor-



A B

Fig. 7. E. K., female, age thirty-eight years; dicondylar fracture of humerus treated originally by Kirschner wire traction but satisfactory position of fragments was not obtained. Two days later open reduction was performed with internal fixation with plate and screws. Skeletal traction was continued for two weeks after operation and patient performed active elbow exercises while in traction. A and B, anteroposterior and lateral views in traction postoperatively showing excellent position of fragments. Late result four years later showed full function and use of elbow without any deformity.

table and maintained position accurately. Her late follow-up at eight and one-half years showed her to have full shoulder and elbow function, but a growth disturbance amounting to 7.5 cm. shortening of the humerus. Another severe injury of the "truck-swipe" variety with compound fractures of the humerus, radius and ulna at the elbow with partial loss of bony substance and with associated radial and ulnar nerve paralysis was put up in Kirschner wire traction (slightly more distally placed in the ulna) following operative débridement for lack of other means of immobilization. This patient had to have several subsequent sequestrectomies performed and subsequent plaster immobilization. His late result seven and one-half years after injury shows a semi-flail elbow, but one with a range of active (and strong) motion from 30 to 140 degrees. Another sixteen-year old girl following an arthroplasty operation for an unreduced elbow dislocation of four years' duration was brought back into the hospital for Kirschner wire traction five weeks after operation in the hope of improving her motion range. She was a psychiatric case and very uncooperative and finally had to be returned to a mental institution. No late follow-up is available. One other case in which postoperative use of skeletal traction was employed was in a fifty-seven-year old woman with fractures of the capitellum, trochlea, radial head and coronoid. At operation the radial head was excised, as was also the capitellum and most of the trochlea. This patient obtained only a fair result after two years.

The fourth group of cases in which Kirschner wire traction was used both prior to and following operation consists of four cases. (Fig. 7.) Two of these were dicondylar fractures. The first did not show satisfactory reduction from the traction and was operated upon two days

later with good internal fixation obtained. After operation the traction and suspension were continued and the patient started on active exercises at two days. Traction was continued for thirteen days. The result at the end of more than four years was perfect in every standpoint except for five degrees of limitation of full elbow flexion. The second had a displaced fracture of the capitellum in addition to a dicondylar fracture. Traction did not reduce the former, and open reduction and replacement of this fragment was performed after one day. Traction was discontinued after four days and active exercises were begun on the twenty-fifth day. The result after four years was perfect except for 5 to 10 degrees limitation of elbow extension. The third case was a fracture of the shaft of the humerus, mid-third, in a bone involved with Paget's disease (osteitis deformans). The traction was used prior to operation for immobilization while blood studies and the patient's general condition were being evaluated. At operation the fracture was reduced and rigidly fixed internally with plate and screws. Traction was continued for four days after operation. The patient has been followed for eight and one-half years since operation and his result has been completely perfect from all aspects. The fourth case of this group was in a fifty-year old woman with an unreduced elbow dislocation of two weeks' duration. Attempts to reduce this had been tried on two occasions before she came to us for treatment. Swelling and induration were extreme and some visible callus was seen along the posterior aspect of the lower humerus on x-ray films. Her elbow was put up immediately in Kirschner wire traction and twenty-four hours later another attempt was made to reduce the posterior dislocation, but without success. Two days later open reduction was performed with difficulty. Traction was continued for only four days after operation. Active exercises were begun on the ninth day. Owing to the fact that this patient developed a marked myositis ossificans, she obtained a poor result from a functional standpoint. Flexion and extension were limited to approximately five to ten degrees although pronation and supination remained complete. She had a strong and painless elbow one year and nine months after operation. The traction although it failed to assist in obtaining a closed reduction, could hardly be expected to do so in such a late case. The poor ultimate result may be attributed to the formation of myositis ossificans started by repeated attempts to bring about closed reduction and encouraged by open reduction at the wrong time (i.e. during the time when it had begun to appear on x-ray films). Such a patient should have been operated upon immediately after the first attempt at closed reduction was found to be unsuccessful.

SUMMARY

1. A series of ninety-three cases of elbow and upper arm injuries treated by means of overhead traction and suspension by means of a Kirschner wire in the olecranon has been discussed in detail and an attempt to evaluate the results of the method has been made.

2. In the first group of thirty-nine cases of supracondylar fracture of the humerus in children the method has been ideal for obtaining and maintaining reduction and in overcoming serious threat to the circulation. It has made it practically unnecessary to perform open reduction for this fracture and once the traction was instituted, all fear of Volkmann's paralysis has been dispelled. Not a single catastrophe of this nature has resulted in 402 cases of all types of supracondylar fractures treated over a period of sixteen years.

3. In another group of fifty-four cases of miscellaneous fractures, etc., in the region of the elbow and upper arm the method has been found especially useful in the treatment of badly comminuted dicondylar fractures of the humerus and in compound fractures of the elbow region or shaft of the humerus. For injuries at the upper extremity of the humerus the use of this form of traction has a limited range. In dicondylar fractures without comminution its greatest use was as a preoperative and postoperative measure.

FACTORS WHICH MODIFY THE CHOICE OF ANESTHESIA IN THE SURGERY OF TRAUMA

SIDNEY C. WIGGIN, M.D.

Professor of Anesthesiology, Tufts College Medical School; Director of Anesthesiology, Boston City Hospital; Consultant in Anesthesia, Bedford Veterans Hospital.

Boston, Massachusetts

WORLD War II demonstrated the value of modern technics of anesthesia and surgery in handling the severe traumatic injuries involving the vital organs and structures of the human body. Since the advent of the specialty surgical teams during the war, experiences gained in surgery and anesthesia have been applied by the surgeon and anesthesiologist to the many civilian, industrial, home and traffic accidents in the surgery of trauma. One lesson learned has been that the proper handling of anesthesia plays an important rôle in the condition of the patient and the outcome of the operation. All cases in the surgery of trauma are initially emergency operations, but for the purpose of reconstruction or plastic repair may be secondarily elective operations. In these cases there are many factors which modify the choice of anesthetic agents and methods of administration. There are those due to the general condition of the patient and others which are the direct result of trauma or incidental to trauma.

In this discussion it will be shown that the choice of an anesthetic agent is modified more by the analysis of the complicating factors rather than the proposed surgery. For example, a patient with a rupture of the liver and in shock from hemorrhage cannot be given a high spinal anesthesia, as an elective abdominal operation would receive, but would be treated for shock first and then be given regional anesthesia (field block with 1 per cent novocaine) supplemented with cyclopropane-oxygen.

Let us first consider the more important factors entailed in the general condition of the patient. These are the age, blood pressure, respiratory, cardiac, trauma in the presence of thyroid disease, renal and hepatic factors.

The very young and very old are two age groups which deserve special consideration. The metabolic rate in both groups are so reduced that they cannot tolerate depressing and toxic drugs for pain relief. In operations above the diaphragm, cyclopropane-oxygen gives the safest control for these extremes of age in the presence of shocking injuries. Below the diaphragm regional anesthesia combined with cyclopropane-oxygen is indicated in these individuals if debilitated from shock or disease. If the patient is in good physical concition, these operations are best performed with spinal anesthesia with or without cyclopropane-oxygen. In surgery of the extremities in the senile as amputation of the lower extremities, refrigeration anesthesia may be employed to good advantage. Regional anesthesia in the senile may often be sufficient for the large majority of operations in either upper or lower extremities, especially in severe trauma to the upper extremities, as compound fracture of the humerus, or severed tendons of the hand or wrist.

If a high blood pressure is recorded, it should be determined whether the cause is of a psychogenic or pathologic origin. Usually a functional type of hypertension responds to preliminary medication, whereas the hypertension of pathologic origin remains high in spite of the action of the basal drugs. The hypertensive patient tolerates both general and spinal anesthesia well, but does not tolerate a fall in pressure from drug action. For this reason, a vasoconstrictor drug as ephedrine or neo-synephrine helps to maintain the patient's preoperative blood pressure level. Hypotension is usually the result of shock from trauma or loss of blood, although it may be of a functional nature. If the hypotension is the result of trauma, the patient will be treated for shock prior to surgery. Even in the presence of moderate shock or hypotension of debilitating disease as tuberculosis, the vasoconstrictor drug, neo-synephrine, in a three minimum dose and repeated for three doses if necessary will maintain or raise the blood pressure. If this fails to correct the condition, fluids and blood transfusion should be administered.

In the presence of respiratory tract disturb-

ance, for operations of the upper body regional anesthesia should be employed as much as possible, with intubation of the trachea under topical cocaine for the administration of oxygen or cyclopropane-oxygen. For operations in the lower body or extremities, spinal anesthesia is indicated.

Bronchial asthma presents a real problem. Morphia and the barbiturates are contraindicated because of the dangers of precipitating marked bronchial spasms. Chloral hydrate or paraldehyde as a preliminary is tolerated by the asthmatic. Atropine is combined to this basal hypnotic drug to allay vagal reflexes and dry secretions. Nitrous oxide-oxygen-ether is given cautiously because of the retarded induction caused by the slow absorption of the anesthetic in the alveoli due to the spastic bronchi. Oxygen must be kept at a high concentration at all times. If extreme bronchial spasm is present, helium 79 per cent and oxygen 21 per cent should be added to the mixture to facilitate the passage of the gases through the spastic bronchi. In external chest operations regional anesthesia with oxygen should be used. In intra-abdominal and lower extremity operations, spinal anesthesia with oxygen is employed. In traumatic conditions of the respiratory and upper gastrointestinal tract, intratracheal anesthesia with cyclopropane-oxygen under pressure prevents collapse of the lungs in the presence of open pleura and allows for positive pressure with oxygen and aspiration of secretions from the lower respiratory tract.

In severe cardiac disease, special care should be taken to administer the minimum of anesthetic agent and a maximum of oxygen concentration throughout the operation. Regional anesthesia supplemented with cyclopropane and oxygen is to be preferred. If severe arrythmia of circulation develops, a shift to ether and oxygen in the closed system should be made.

In the cardiac patient, operations involving the extrenal thorax or upper extremities may be best handled with pentothal sodium 2½ per cent supplemented with 50 per cent nitrous oxide-oxygen which may be reinforced with cyclopropane-oxygen intermittently rather than forcing either the intravaneous agent or nitrous oxide. This will provide a high concentration of oxygen throughout the operation and allow the patient to be awake with complete control of reflexes at the end of the operation. In intrapleural or transthoracic operations intratracheal administration of cyclopropane or ether with high oxygen concentration is indicated. The intubation is done under topical pontocain in 3/10 of 1 per cent solution. In the presence of the more severe cardiac disorders, regional anesthesia supplemented with oxygen intratracheally should be employed. In operations below the diaphragm, balanced continuous spinal anesthesia with minimum doses of spinal agents combined with cyclopropane-oxygen gives maximum duration and relaxation. In the lower extremities, spinal anesthesia with a very low does of the agent combined with the oxygen is sufficient for most operations.

Patients with non-toxic conditions of the thyroid gland present no special problem in anesthesia for the surgery of trauma; but emergency cases with toxic thyroid, however, especially when complicated with cardiac insufficiency, require very careful consideration. The patient treated today with thiouracil preparations demonstrates less toxic signs and responds well to cyclopropane-oxygen anesthesia for upper body operations and spinal anesthesia for operations below the diaphragm. If there is a large degree of toxicity present, the patient should be controlled principally with regional anesthesia supplemented with 50 per cent nitrous oxide-oxygen in operations above the diaphragm. If this technic is not favored in operations above the diaphragm, sodium pentothal 2½ per cent solution for induction may be supplemented with local field block with 1 per cent procaine and cyclopropane-oxygen administered. Below the diaphragm operations are best performed with spinal anesthesia. In the patient with thyrotoxicosis, the chief dangers are from sudden cardiac collapse, which is believed to be due to an abnormal stimulation of the sympathetic system and an overproduction of adrenalin. Spinal anesthesia in these cases has proved to be of value in preventing this complication evidenced by tachycardia and hypertension in these patients during operation, by depressing the sympathetic system, especially the sympathetic plexus controlling the adrenal glands. Intratracheal intubation is employed only in the very toxic thyroid patient or in the presence of dislocation of the trachea by tumor with respiratory tract obstruction.

If kidney function is insufficient from renal disease, the toxic volatile anesthetics and bar-

biturates are contraindicated. Cyclopropane-oxygen and regional anesthesia in the upper extremities and above the diaphragm and spinal anesthesia or regional below the diaphragm prevent any depression of renal function.

In liver disease the chief contraindication is any anesthetic agent which causes liver damage as ether, chloroform, ethyl chloride or avertin. These patients tolerate gas oxygen well for operations above the diaphragm and spinal anesthesia with minimum doses supplemented with cyclopropane-oxygen for operations below the diaphragm.

With modern control of diabetes by insulin and diet the diabetic patient is able to tolerate any of the anesthetics of choice best adapted to the existing traumatic conditions. Spinal anesthesia should be used for all operations below the diaphragm and lower extremities. The more toxic agents as ether which depress the vital organs should be eliminated as much as possible. Cyclopropane-oxygen is a good substitute for ether, especially when supplemented by regional anesthetic agents.

The factors influencing the choice of anesthesia for the patient in the surgery for trauma which are the direct result of trauma or incidental to trauma are coma, alcoholism, excitement, shock from trauma to the central nervous system, tissue damage and hemorrhage; foods, liquids, or blood in the stomach; and respiratory obstruction from extrinsic causes, as external injuries to the neck, oral cavity, chest, spinal region, and intrinsic causes as spasms of upper or lower respiratory tract from foreign body or other reflex causes.

A careful history should be taken on the unconscious patient from the most available sources combined with a complete physical and laboratory examination. Here one must differentiate between trauma to the brain or disease of this organ, coma due to diabetes, kidney, or circulatory diseases, alcoholism or other drug poisonings. In comatose patients with brain or respiratory tract involvement, intratracheal intubation under topical pontocain in $\frac{3}{10}$ of 1 per cent solution should be instituted for the administration of sufficient oxygen to prevent hypoxia and to perform positive pressure when indicated and also to allow for frequent aspiration of secretions.

The alcoholic will require gastric lavage and the introduction of a Levine tube through the nasal passage which is left in the stomach for drainage. Care should be taken not to administer morphia or ether as the brain is already edematous. This would increase the danger of acute cerebral edema and immediate death or the danger of delerium tremens postoperatively. In operations above the diaphragm, rectal paraldehyde 15 to 30 cc. per 100 pounds of body weight supplemented with gas-oxygen (cyclopropane) intratracheally will provide sufficient anesthesia and prevent the cerebral or respiratory complications so commonly seen with the use of morphia or ether in these patients during operation and postoperatively. In operations below the diaphragm and the lower extremities of the alcoholic patient, spinal anesthesia furnishes the safest pain relief and relaxation for surgery. If the patient is uncontrollable with this technic, spinal anesthesia should be supplemented with cyclopropane-oxygen.

The emotionally imbalanced patient requires encouragement and reassurance together with sufficient basal narcosis to allay fear and apprehension. Intravaneous morphine and scopolamine may be given immediately preceding anesthesia for basal effect. Intravaneous pentothal sodium $\frac{1}{2}$ per cent solution will give a quick induction for gas-oxygen anesthesia. If spinal anesthesia is employed, it may be supplemented with cyclopropane-oxygen before or after the spinal is administered. This is especially applicable to uncontrolled children. If cyclopropane is kept at a very low concentration, the patient is kept asleep during the whole operation but will be conscious immediately postoperatively.

Before anesthesia is considered for the patient in shock, the cause, type and degree of shock should be determined. If the shock is severe, the operation is postponed. Fear and apprehension should be alleviated early by the use of hypnotics and morphia. If the hemorrhage is external, it should be brought under control and the treatment of shock should be instituted with supportive therapy as soon as possible. Intravaneous fluids should be started at once with glucose 5 to 10 per cent in saline immediately followed by whole blood or plasma as indicated as soon as it is obtainable. To relieve the complication of hypoxia from loss of hemoglobin, oxygen should be immediately administered. The most controllable method of pain relief in cases of shock above the

diaphragm, is the administration of cyclopropane oxygen with intratracheal intubation introducing the tube under topical pontocain in 3/10 of 1 per cent solution. Wherever possible, regional anesthesia should be employed for speed and safety in the care of the patient in severe shock. This allows for the administration of oxygen to support the patient in this collapsed state. If it is necessary, the regional anesthesia may be supplemented with cyclopropane-oxygen, keeping the oxygen at a maximum concentration. However, if after the treatment of the shock condition the patient responds favorably and the blood pressure is stabilized above 100 mm. systolic, spinal anesthesia in minimum doses may be balanced with a light concentration of cyclopropane-oxygen in operations below the diaphragm and lower extremity operations.

The patient whose stomach contains food, liquid or blood should not be subjected to a general anesthetic for major operations. If general anesthesia is imperative, gastric lavage should be performed at once and a Levine tube left in the stomach for drainage. Any patient with stomach contents or suspicion of the same, should be intubated with a balloon-catheter before any general anesthetic is administered. The tube may be introduced before induction of the general anesthetic—under topical pontocain in 3/10 of 1 per cent solution. If the patient has been given a general anesthetic and vomits during induction, the anesthetic should be discontinued at once, and the head of the patient carried over the side of the operating table in Trendelenburg position. Vomiting should be initiated and the patient allowed to regain consciousness to the point of a cough reflex in order to expell any foreign material from the lower respiratory tract. The mouth and throat should be thoroughly aspirated before reinduction of the anesthetic is instituted. If vomiting takes place during the operation and there is need for continuing the anesthesia, an intratracheal tube should be passed which allows aspiration of the bronchi with a suction catheter. The intratracheal tube is left in place and the anesthesia is continued after carrying the patient to a deeper plane to avoid possibility of more vomiting. Immediately after operation, bronchoscopy should be performed with aspiration of the lower respiratory tract. To avoid dangers of vomiting in these cases spinal anesthesia should be employed in all operations below the diaphragm and lower extremities. When general anesthesia is imperative for minor surgical emergenices such as reduction of simple fractures or painful dressings, it may cause serious complications in the patient with a full stomach. For these emergency procedures the safest and the quickest reversable method of anesthesia is the administration of nitrous oxide-oxygen by the supersaturation technic. Without the use of any basal drug the patient is induced with a high concentration of nitrous oxide to a preasphyxial state, without allowing cyanosis, stertorous breathing or convulsive twitchings. At this point oxygen is added in sufficient quantity to maintain the patient in first plane of third-stage anesthesia. This level of anesthesia controls all tissue reflexes involved in these minor surgical procedures. The patient returns to normal reflexes and consciousness after the first few inhalations of oxygen and the removal of the nitrous oxide. If vomiting should occur, the protective reflexes of the respiratory tract are present before the vomiting reflex is initiated.

Respiratory obstruction is the most critical complication which can occur during anesthesia. Before an anesthetic is chosen in any emergency operation the cause of obstruction to the respiratory tract must be determined by close examination. Nasopharyangeal, oral, laryngeal and lower respiratory tract examination with laryngoscope and bronchoscope should be performed. Extrinsic and intrinsic causes of respiratory obstruction must be diagnosed before the administration of anesthesia. In a case of severe respiratory obstruction with impending death tracheaotomy should be performed immediately with the introduction of a suction catheter for aspiration of the trachea and the administration of oxygen through another catheter for resuscitation of the patient. The facilities for immediate administration of a general anesthetic whether inhalation or intravaneous should be available to control the patient's reflex as soon as the patient is revived and to carry out the surgical procedure. For operations above the diaphragm with respiratory obstruction, inhalation anesthesia preferably with cyclopropane-oxygen should be administered intratracheally. If the obstruction is not severe and can be controlled, intravaneous pentothal 2½ per cent solution may be used with nasal catheters in each nostril, one being attached to a gas-oxygen

machine for the administration of nitrous-oxide-oxygen 50 per cent. Injuries to the neck and chest complicating the normal respiratory tract function should be anesthetized with intratracheal cyclopropane-oxygen; or if respiratory obstruction is severe, the inhalation anesthesia should be administered through a tracheotomy tube. Where intratracheal anesthesia is being employed to relieve a severe respiratory obstruction, the intratracheal tube should be left *in situ* postoperatively until the cause of the respiratory obstruction is relieved. If the obstruction persists so as to endanger the life of the patient, a tracheotomy tube should be inserted as the intratracheal tube is being removed in order to preserve a patent airway. Below the diaphragm, operations complicated with respiratory obstruction are best anesthetized with a minimum of spinal anesthesia combined with intratracheal cyclopropane-oxygen. In operations on the lower extremities, a low dose of spinal anesthesia supplemented with oxygen will prevent any serious accident in the presence of respiratory obstruction. Regional anesthesia supplemented with light cyclopropane-oxygen is indicated when other technics are contraindicated.

Many of the factors which modify the choice of an anesthetic for emergency cases are to be found in the elective operations in the surgery of trauma, except that the condition of the patient is usually better after supportive and resuscitative treatment following the preliminary emergency operation. In the elective cases it is possible to prepare the patient more completely with basal drugs and the patient is able to tolerate a more complete anesthesia. The elective case differs from the emergency case in that the surgery is of a more reconstructive nature and requires a choice of agent to obtain a longer lasting anesthesia. For example, instead of a regional block of a nerve or a nerve plexus which may wear off in the course of an hour, the patient will be able to tolerate a total or continuous spinal anesthesia for an operation below the diaphragm or a lower extremity operation lasting several hours, or a choice of any of the general anesthetic agents for upper extremity procedures may be made best suited to the patient.

In operations about the head, if the patient's condition is not too serious, intravaneous pentothal 2½ per cent solution supplemented with 50 per cent nitrous oxide-oxygen is indicated. This technic may be employed for either long or short operations involving the brain or external tissues of the head, nose and throat, and oral operations. The anesthesia of election for short operations about the face, or oral cavity, which are not going to interfere with respirations, is pentothal sodium 2½ per cent supplemented by nitrous oxide-oxygen with the double catheter technic employed. A nasal catheter is introduced in one nostril for exchange of gases and exit of any excess secretion and another is inserted in the other nasal passage for introduction of nitrous oxide-oxygen—50 per cent mixture. In the oral cavity the surgeon packs gauze back to the two nasal catheters to prevent blood or foreign bodies from passing into the oropharynx. In fractures of the jaw, regional block anesthesia requiring wiring of the jaws prevents the dangers of aspiration of vomitus which is likely to complicate general anesthesia, but more seriously to cause atelectasis and massive collapse of the lungs. In external chest or abdominal and upper or lower extremity operations as skin grafts or burns or other denuded areas, cyclopropane-oxygen or sodium pentothal 2½ per cent solution supplemented with 50 per cent nitrous oxide-oxygen will be sufficient for control of pain.

In abdominal operations if the patient's condition warrants it, spinal anesthesia with minimum doses of the agents supplemented with cyclopropane-oxygen provides a safe control. In long abdominal operations continuous spinal anesthesia with minimum doses of the agent balanced with cyclopropane-oxygen provides satisfactory anesthesia. If the patient is in serious condition, spinal anesthesia is contraindicated and local infiltration with 1 per cent novocaine supplemented with cyclopropane-oxygen provides sufficient relaxation for this type of patient. With either technic to complete relaxation curare may be administered intravaneously to good advantage.

In operations on the spine two considerations are of most importance. First is the prevention of pressure on the abdomen interfering with diaphragmatic excursion by placing a pillow under the pelvis and the chest. Second, in cases requiring casts, as spinal fusions or upper vertebral operations intratracheal anesthesia should be used leaving the intratracheal tube *in situ* until the patient is conscious in order to prevent laryngeal or bronchial spasm by removal of the tube before the patient is in control of his own

reflexes. Operations on the upper extremities with patients in poor condition are best done with brachial plexus block, whereas operations in the lower extremities are best performed under low dose spinal anesthesia. Operations on the femur in senile patients as hip-nailing or plating of spiral fractures of the shaft of the femur are best done with very low dose spinal anesthesia supplemented with oxygen. In the presence of circulatory insufficiency or cardiac disease, oxygen should always be administered. In operations of the lower extremity in little children, as closed reduction of fractures or shaft of femur, spinal anesthesia is an ideal technic, as it gives complete relaxation, with sufficient duration for manipulation, fluoroscopy and x-ray of the bone, without disturbing the patient in any way. Three-year-olds with fracture femurs have received sufficient premedication, then been entertained by their nurse with toys during a reduction application of apparatus and x-ray, and the whole thing repeated because of over-reduction of the fracture with the spinal anesthesia lasting well over three hours.

CONCLUSIONS

In conclusion, in the majority of cases general anesthetics, preferably cyclopropane-oxygen and pentothal sodium, are used for operations above the diaphragm which will allow a high oxygen concentration to be administered. In the patient in poor condition, regional anesthesia for upper extremities is chosen. In the abdomen and lower extremities spinal anesthesia is indicated with the exception of a very bad risk patient when regional and gas-oxygen anesthesia are employed. Sodium pentothal as a total anesthetic is to be condemned as it produces a profound depression of respiration in order to control pain and reflexes, together with the difficulty of keeping an even level of anesthesia, also, there is the danger of vomiting in the emergency cases. Curare is used as an adjunct to a light inhalation anesthesia or pentothal sodium in combination with gas and oxygen and to facilitate the introduction of the intratracheal tube to complete induction if respiratory tract spasm is in excess. Curare is employed where a reduction of the general anesthetic agent is necessary to prevent overconcentration in the patient in poor condition or the general anesthetic is not sufficient to control the reflexes of respiration or the abdomen.

From the beginning to the end, the safety and well being of the patient in the surgery of trauma is of supreme importance. First, the complete knowledge of the patient's condition, secondly, the knowledge of the drugs used in anesthesia and their action on the patient in the presence of disturbed physiology and pathology, and last but not least, the efficient selection and administration of these drugs to obtain the most satisfactory results during and after operation are important requisites.

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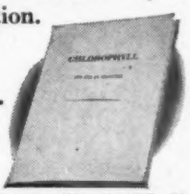

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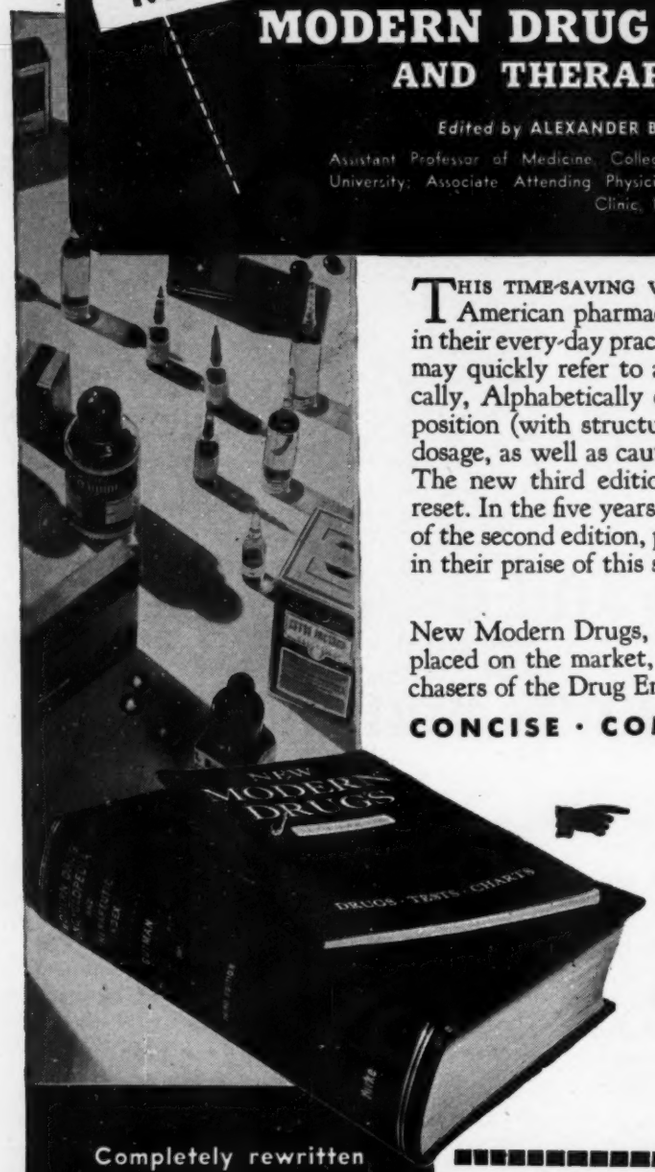

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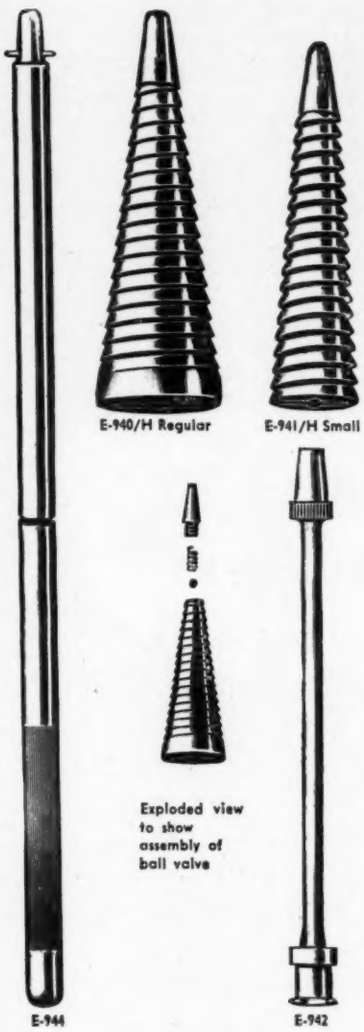

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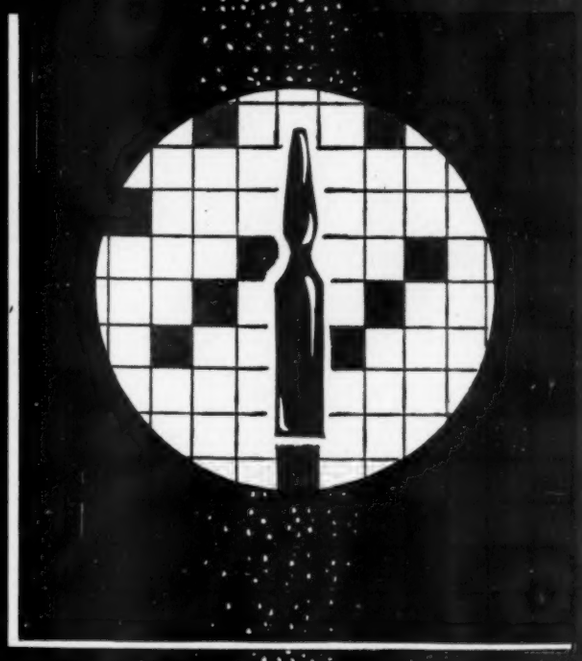

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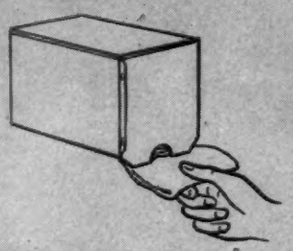

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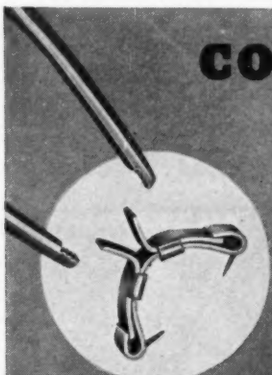

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Edited by Jefferson Browder, M.D.
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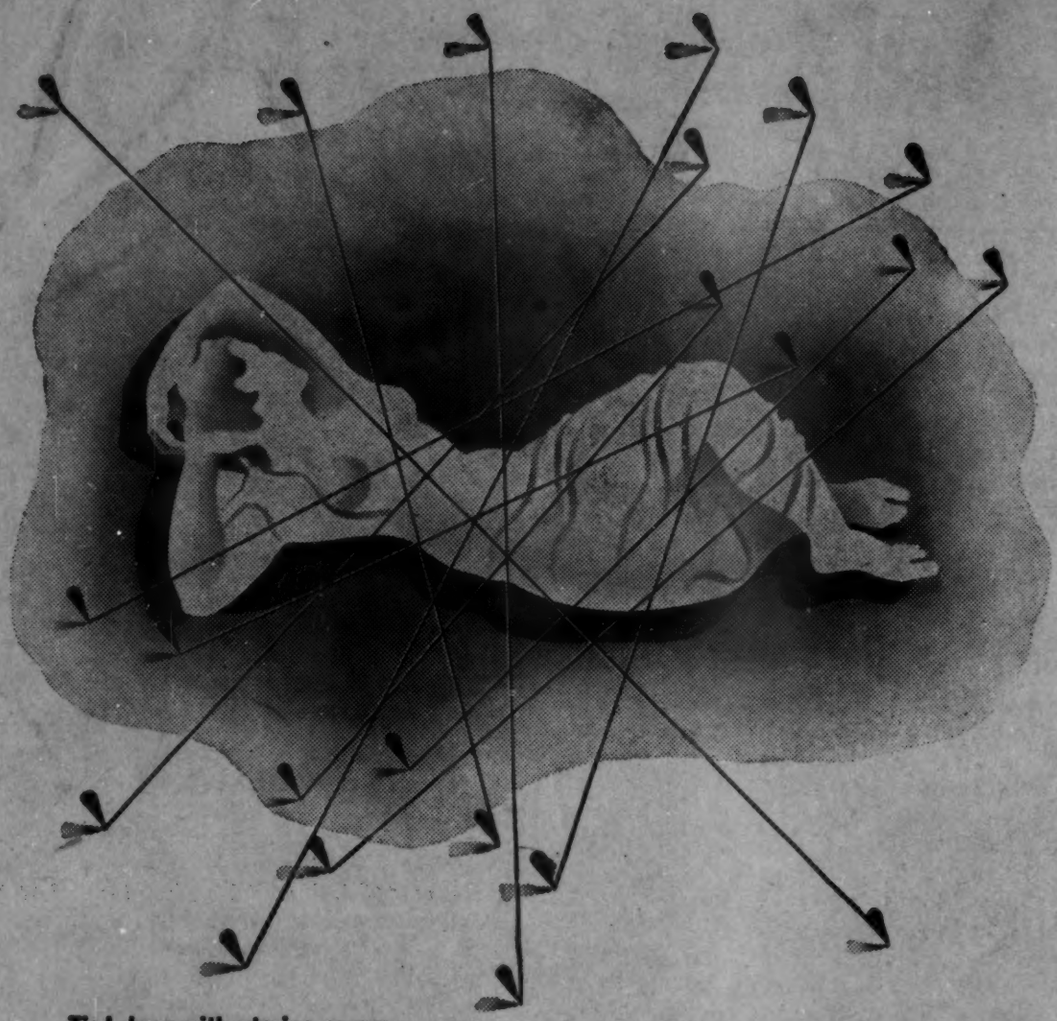

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